A BRIEF HISTORY OF MICROTONALITY IN THE TWENTIETH CENTURY

by

B. McLaren

In less than seven years the 20th century will be over. From this vantage point it's surprising that no comprehensive survey of 20th century microtonality exists.

There are some good reasons, however, for this singular lacuna. Standardized retunable electronic instruments did not appear until 1986. Before that year every microtonalist had to re-invent the wheel.

But now--with desktop supercomputers around the corner, real-time parallel-computing sound engines and retunable MIDI synthesizers available via mail order--microtonality has finally taken off.

And so the time has come for a survey of alternative tuning throughout the 20th century.

There are a number of earlier discussions. Wendy Carlos' 1987 article *Tuning: At the Crossroads* deals with some of the lesser-known figures. *Tuning In*, by Scott Wilkinson, treats just intonation at greater length than most sources. Jean-Etienne Marie's *L'Homme Musicale* deals only with a handful of microtonal composers and confines the discussion of historical figures almost exclusively to the 1920-1950 period. J. Murray Barbour's 1951 *On Tuning and Temperament*, originally a 1932 doctoral thesis, examines the history of tuning in exhaustive detail--but it predates most of the important developments of the twentieth century.

M. Joel Mandelbaum's 1961 thesis *On the Multiple Division of the Octave and the Tonal Resources of 19-tone Equal Temperament* is the most comprehensive discussion to date. However, Mandelbaum's thesis was written before many of the important developments of 20th century microtonality: affordable digital synthesis, FM synthesis, MIDI, digital recording and editing systems, digital sampling, home computers, hard disk recording, computer-based xenharmonic scoring programs like Lippold Haken's LIME, modern digital tuning references and the explosion of "world music" that has showered ordinary listeners in non-12-tone music, plus the recent tubulong and guitar-refretting mass movements spurred by articles in *Guitar Player* magazine, *Keyboard*, *Steel Guitar Player*, *The Village Voice*, *The New York Times*, et al..

APPROACHING THE EDGE: 1870-1899

The history of microtonality since 1900 can't be understood without first considering the musical ferment of the late nineteenth century.

From Wagner to Liszt to Schoenberg, European composers pushed altered chords and lush chromaticism beyond the edge of tonality.

In 1895 the Paris Exposition exposed western musicians to the music of a Balinese gamelan. Edison's 1876 invention of tinfoil-cylinder sound recording, Emile Berliner's 1887 invention of disc recording and Valdemar Poulson's 1898 invention of the magnetic recorder (originally called the telegraphone) allowed sounds outside the standard repertoire of Western music to be recorded and re-ordered in musical ways. **[Holmes, 1985]**

By the 1890s it had become obvious that the sonic universe contained more than 12 pitch-classes.

Western composers began to move outside traditional systems of tonality. Even as early as the 1860s Mussorgsky had forced the 12-tone scale into alien realms: his opera *Boris Godunov* makes effective use of consonant triads descending by non-tonal root movements of diminished fifths.

But by 1881 Liszt's *Nuage Gris* (published posthumously) perambulated extensively through the 6/oct (or whole-tone) scale, a completely anti-tonal system. Claude Debussy's 1892-94 *Prelude a l'apres midi d'un faune* pushed the process further, escaping 12 for long periods in favor of extravehicular spacewalks in the whole tone scale. Except for a brief middle section in 12, his prelude *Voiles* (from Book I, 1910) uses the 6-tone scale exclusively.

At the same time the percussion section of the symphony orchestra expanded explosively. Crotales, tam-tams, thunder sheets, gongs, anvils, guajiros, wood blocks, ethnic drums and finally sirens, propellors, typewriters, electric buzzers and brake drums all made their debut. Kastschei's Dance in Stravinsky's 1910 *Firebird Suite* (suite 1 published 1911, suite 2 for

reduced orchestra published 1919) exalted the percussion section and composers like Varese, Cage, Lou Harrison and Antheil quickly upped the ante throughout the remainder of the 20th century.

Schoenberg's 1900-1901 composition *Gurre-Lieder* marked a kind of *Ultima Thule* of chromatic tonality. Beyond lay his 1909 *Five Pieces for Orchestra* and the realm of free atonality, and beyond *that,* serialism and the exploration of pure timbre (*klangfarbenmelodie*).

These twin divergant forces--the search for new sound-colors on the one hand, and the quest for new systems of musical syntax beyond traditional tonality on the other--tore European art music into kaleidoscopic shards.

Ahead on one path lay Webern, Berg, Krenek, Boulez, Stockhausen, Cage. On the timbral frontier Schaeffer and Henri's *musique concrete* beckoned, along with Varese's *Poeme Electronique*, Mumma's *Hornpipe*, and the computer music of Truax, Dashow, Chowning and Risset.

But there was a third alternative.

"If he had just moved to thirteen equal tones instead of twelve," Jonathan Glasier has pointed out, "Schoenberg could have discovered a new world."

Bosanquet made the jump outside of the 12-tone scale. Much earlier, in his article "Temperament; or the division of the octave," (*Proceedings of the Music Association*, 1874-5, No. 4), he considered the properties of a large number of different equal-tempered scales, focussing in particular on the 22-tone equal-tempered scale.

He was originally led to the scale by considering East Indian music, which divides itself into 22 **un**equally-spaced *srutis*. Bosanquet asked the question: what if the 22 *srutis* were ***equally*** spaced?

In his 1874 article he examined not only the resulting scale but also 31-, 53- and 118-tone equal temperaments and showed how they could be applied to his generalized keyboard.

This keyboard was originally intended for 53 (first proposed in the 16th century by Mercator II, son of the famous map-maker and explorer) but as Bosanquet showed, it proved equally applicable to many different equal tunings.

Bosanquet's generalized keyboard is the most important example of its kind. It is the direct ancestor of the Secor Scalatron generalized keyboard, the Rayna generalized keyboard, Fokker's Archifoon keyboard (a nearly exact inversion of Bosanquet's design), James Piehl's 19-tone organ keyboard, the Wilson-Hackleman clavichord, the Australian Bill Coates' home-built generalized MIDI keyboard and all of Erv Wilson's and Larry Hanson's keyboard schemata. Even recent 12-tone-based systems like the Gulbransen generalized keyboard owe their provenance to Bosanquet's paradigm.

During the same period Hermann Helmholtz investigated the nature of timbre and tonality. The result, *On the Sensation of Tone* (1885), elucidated the physical basis of musical timbre and introduced groundbreaking ideas: a detailed theory of consonance and dissonance based on Fourier Analysis of complex sounds, which led him to propose a just intonation system.

Alexander John Ellis' immense foreword, afterword, and copious notes to Helmholtz' second edition (in English) pushed the idea of just intonation beyond its Greek origins. Ellis introduced a construct he called the duodene; intended as a theoretical exploration of abstract possibilities, it was not musically practical, given the limitations of 1880s technology.

But Ellis' duodene provided crucial inspiration for Ben Johnston, Paul Rapoport, and a host of modern computer music composers. With the advent of direct acoustic-compiled computer music **[Mathews and Guttman, 1959]**, it became not only possible but trivial to specify the exact pitches of the duodene--or of even more complex just intonation systems.

Wendy Carlos' virtuoso modulation through 12 just keys (with 12 different just tonics) in *Just Imaginings* on her album *Beauty In the Beast* probably owes its genesis to Alexander John Ellis in 1885. **[Carlos, 1986, 1987]**

In 1891 Professor Carl Eitz constructed a syllable-system solmnization for 53-tone equal temperament. He mapped the extended syllables (reminiscent of a hyper-sol-fa) onto a two-dimensional Bosanquet keyboard. **[Darreg, personal communication]**

Meanwhile, subdivisions of the 12-tone scale began to appear. In 1893 (also in Germany) there appeared a brochure signed "Behrens Senegalden," proposing to build a quartertone piano and suggesting a notation for the resulting music. **[Marie, 1983]** In Odessa in the same year the Russian futurist composer Aleksander Lourie produced trumpet music in the 24-tone system. Louire was subsequently to produce quartertone work throughout the teens and 20s. **[Marie, 1983]**

In 1895 the Mexican composer and theorist Julian Carrillo first produced on his violin what he called "the thirteenth sound"--the first interval beyond the 12th of an octave. **[Carillo, 1925]**

Finally, starting in 1896, Thaddeus Cahill filed a series of patents on the dynamophone--later called the Telharmonium. This was the prototypical synthesizer, generating tones by means of 145 rheotome/alternators (one rheotome, or cogged tone-wheel, per overtone; 6 overtones per alternator for the lower 5 octaves and 4 for the upper 2) which rotated at the desired frequencies. **[Holmes, 1985; Baker, 1906]**

The Telharmonium was not limited to the frequencies of the 12-tone scale. Its 145 alternators were each attached to an eleven-inch section of a steel pitch shaft divided into eight groups, 30 feet in cumulative length (two boxcars full of alternators, rheotomes, a huge mixing transformer, 2000 contact switches and 18-inch steel girder supports, 200 tons in overall weight, pulling enough amperage to shut down phone lines throughout a four-block area) could produce *any* desired set of intervals--given the proper rheotome tooth-spacing. Although it ultimately proved impractical, Cahill's telharmonium was the seed from which all subsequent synthesizers sprang. Even the touch-sensitive polyphonic keyboard of the Telharmonium, replete with stops and "expression devices" for controlling each overtone's pitch and amplitude, looks forward to the so-called "alternative MIDI controllers" now becoming available. **[Baker, 1906; Holmes, 1985]**

With the Telharmonium capable of synthesizing additive tones of any musical pitch and timbral structure... With new composers advocating a rainbow of competing just intonation and equal-tempered systems... The stage was set for the eruption of completely non-12-tone systems in the early 20th century.

THE EARLY PERIOD: 1900-1920

The first major 20th century figure in microtonality is Paul von Janko. His article "Uber mehr als zwoelfstufige gleichschwebende Temperatur" ("Concerning equal-temperament with more than twelve scale-steps") appeared in 1901 in the publication *Beitrage zur Akustik und Musikwissenschaft*, and extolls the 41-tone equal tempered system.

Janko was a hugely important figure whose contribution has largely been ignored. He was the first to explore a wide variety of completely non-12 systems; Janko examined the 31-tone, 43-tone and 46- and 53-tone systems before settling on 41 as his ideal.

It's unclear whether Janko intended the 41-tone system to be considered as a purely theoretical construct, along the lines of Ellis' duodene, or as a practical goal. Clearly it would have been extremely difficult to tune a 41-tone instrument accurately in 1900.

Regardless of Janko's intent he was among the first to consider the advantages of the 41-tone system. (Sauveur is one of the few others; he, however, favored 43.)

Janko also designed and built a keyboard applicable to non-twelve tunings. The Janko piano keyboard, with 6 black keys and six white keys, remains one of the most important practical examples of a non-standard klavier which was actually built. Some instruments using this keyboard can still be found today.

Non-12 keyboards have continued to concern xenharmonic composers and inventors,and the so-called "generalized keyboard" has important repercussions today. Mandelbaum (1961) identifies 3 principles distinguishing the generalized keyboard from its inefficient cousin, the piano/organ/harpsichord/clavichord keyboard:

[1] Keys must be arranged in a completely regular pattern, which implies a uniform shape for all keys. (Rotational invariance.)

[2] The succession of keys along any bank or in any given direction must always involve the same interval (Intervallic isotropy.)

[3] There must be many extra keys so that any pitch is available within the span of ten fingers. (The keyboard should be a large two-dimensional plane.)

Janko constructed his keyboard and applied it to a 12-tone piano. As noted above, this was likely due to the technical and practical difficulties of tuning and building an action for a non-12-tone instrument. Regardless, Janko's 6-black, 6-white key klavier exerted an important influence and continues to shine as a touchstone of non-12 keyboard design. (The Esperanto interest group *Musika 6-6* in fact advocates this same design today.)

In 1901 Max Meyer wrote *Contributions to A Psychological Theory of Music*. **[Meyer, 1901]** Bucking the equal-tempered trend of the period, he proposed an empirically-derived 29-tone 7-limit just intonation scale.

Von Janko's inability (or unwillingness, after proposing a highly microtonal scale) to tune or construct a 41-tone instrument because of the technical limitations of the day cannot have gone unnoticed. Given the primitive frequency-measurement and frequency-generation technologies of the 1890-1910 period (tuning forks, Helmholtz resonators, monochords) only simple divisions of the conventional semitone (subdivisions of 1/12 octave) were practical for performance in a concert setting.

Many composers must have noticed this. And they took the path of least resistance in expanding tonality.

Richard H. Stein was the first composer to publish a 24-tone piece. His *2 Pieces for Cello and Piano* were issued in 1906. **[Mandelbaum, 1961; Marie, 1983]**

In the same year Feruccio Busoni built a three-rank harmonium. Each set of reeds was tuned 1/36 of a tone apart,

allowing both 36-tone and 18-tone compositions. **[Busoni, 1916]**

Influenced by Baker's 1906 articles on the Telharmonium, Busoni wrote *Sketch of a New Esthetic of Music* (1906; translated and published in English in 1911) advocating the use of the 36-tone system as "the next step" for Western music. In fact he proposed using 18-tone melodic lines harmonized with 36-tone chords. Like the 6-tone system, 18 is a completely anti-cadential, non-tonal tuning. It has nothing like a perfect fifth.

Busoni surely realized this. No doubt this is why he made the jump to 36-tone. Unlike 18, the sixth-tone system offers the same excellent perfect fifths available in 12: 700 cents, versus the 701.955-cent third harmonic found in nature.

Other composers and instrument builders jumped on the bandwagon. In 1909 Engbert Brandsma presented the paper "Concerning Tonality in Old and New Music," published in the *Proceedings of the 3rd Congress Of the International Society of Musicology*, pg. 387. In 1910 Jorg Mager constructed a harmonium (a small reed organ pumped with a pedal) using 1/4 tones--that is, 24 tones per octave. He also devised a notation. **[Mandelbaum, 1961]** Mager went on to become an electronic pioneer, later inventing the Sphaerophon. (See 1920-1940 section for more information.)

In 1914 Willi Moellendorf constructed a harmonium capable of sounding quartertones and in 1917 he published the pamphlet *Musik mit Vierteltoenen* (Music in Quartertones), Leipzig, Verlag von F. E. C. Leuckart. Most of the tract is taken up with a defense of quarter-tone music against charges that it is too extreme: by present standards, Moellendorf would be considered excessively conservative. However, he **does** note that the 24-tone system is composed of 2 distinct 12-tone circles of fifths pitched one quarter-tone apart. This is the first discussion in the microtonal literature of scales with multiple circles of fifths, and is important for that reason (if for no other). **[Mandelbaum, 1961]**

The bulk of the pamphlet is devoted to modulation formulae allowing the composer to jump from one circle of fifths to the other.

The rest of the tract is filled with counter-arguments to the most common criticisms of quarter-tone (or for that matter, any kind of new) music: viz., that quarter-tones will make people more nervous, that they will destroy tonality, that all present music will have to be re-composed, and the singularly Germanic charge that 1/24s of an octave represent a "primitive, even barbaric condition of a lower cultural level." (Shades of Himmler and Heydrich.)

Across the border, in France, Malherbe studied the practicality of instruments and notations (also in 1914) permitting the utilization of 1/3 and 1/6 tones. It is likely that Malherbe was influenced by Busoni's experiments and article.

New tuning systems were in the air. In 1912 an anonymous interview with a futurist led to a discussion of 53-tone equal temperament, in part because $E^{bbbb} = D^{\#\#\#\#}$. And at the conclusion of his *Study of Twentieth Century Harmony,* **[Mandelbaum, 1961]** Rene Lenormand wrote in 1914: "We should see formulas arise of which we cannot at present foresee the character."

In Italy in 1918 the futurists Russolo and Marinetti issued a manifesto calling explicitly for the adoption of microtonality. "...the intonarumori can produce any fractions of tones. It is necessary, therefore, to find an easy and simple means to indicate these subdivisions..." **[Clough, 1965; Russolo & Marinetti, 1918; Russolo, 1914]** Russolo examined, then discarded, the notion of writing down individual pitches as numbers (anticipating Julian Carillo's proposal 20 years later). Instead, he settled on a notation using what he called "the line-note," remarkably similar to subsequent electronic music notation systems.

To explore this "enharmonic universe of sound" Futurists built a set of mechanical instruments--an orchestra of noisemakers, designed to create what Russolo called "the art of noise." The instruments used various permutations on scraped, struck or bowed membranes, along with ratchet-type and rotating rattles, clackers, and grinders. Their wonderfully vivid names summoned up a new universe of sound: an orchestra of "sobbers," "wailers," "shriekers," "exploders."

The Italian futurists were explicitly microtonal. Their few surviving scores bear an uncanny resemblance to the graphs James Tenney used to design his computer composition *Ergodos I,* and the pitch curves specifically delineate the frequency of each noisemaker at any given instant. Russolo himself wrote specifically on the subject:

"Enharmonic music as...performed by the *intonarumori* has as its characteristic the possibility not only of fractionizing the interval of a tone into a given number of parts, but of giving precisely the change from one tone to another, the sliding as one could say, that a tone makes in order to arrive at the tone immediately above or immediately below it." **[Radice, 1989; Russolo, 1914]**

In fact it is worth pointing out that the futurist scores could only be performed exactly as written today, with the advent of direct-to-disk acoustically compiled computer music. It would be a fascinating project to translate Russolo's and Marinetti's scores into a computer event list and generate the resulting sounds.

THEORY VS. PRACTICE: 1920-1940

The most adventurous microtonal explorations in the 20s took place in Russia.

This, like Janko's work and the efforts of the Italian futurists, is a chapter of musical history that has been largely abridged and forgotten.

Both before and after the 1917 Communist revolution, Europe continued to regard Russia as a musical backwater. Soviet musicians and artists were treated with disdain (with a few exceptions--notably, Prokofiev). By 1948, Stalin's tyrannical *apparatchik* Zhdanov effectively silenced all serious musicians in the Soviet Union. The 1948 edicts condemning hordes of musicians for "anti-Soviet" and "counter-revolutionary bourgeois" sentiment, or conversely, for "sterile constructivism," left virtually no avenue open for serious composers to pursue their art. Anything other than a patriotic song was an invitation for the NKVD to haul the composer off to a gulag. **[Carpenter, 1983]**

Little wonder, then, that Soviet microtonality has fallen through the cracks of history. Between the disinterest of the Eurocentric West and the depredations of Stalinist censors, it's surprising that *any* record remains of the extensive soviet experiments with alternative tunings in the 20s.

As early as 1908, Boleslav Yavorsky's *The Structure of Musical Speech* and Sergei Taneev's *Movable Counterpoint In the Strict Style* set forth a surprisingly modern thesis: that music must be treated with the mathematical tools of acoustics and physics. (No institution of higher learning was to duplicate this effort until the investigations of Risset at Bell Labs in the early 1960s and the efforts of Chowning, Schottstaedt , Grey and Moorer at Stanford in the 1970s and early 1980s, along with the work of David Wessel at Berkeley around the same period.)

Yavorsky writes: "Only when the sufficiently fantastical so-called theory of composition is turned into a musical science that examines the laws directed by musical thought and expressions, and on the basis of these laws constructs an edifice of musical creation...will there appear the history of musical art." **[Carpenter, 1983]**

In 1912 Leonid Leonidovich Sabaneev (one of the most important Russian microtonalists) wrote: "Essentially music as a science...is really just born." He was distinctly unimpressed by musical "science" before his time. "Everything that previously existed was one continuous uncultured misunderstanding, musical sorcery... the writing of prescriptions, devoid of any hint of system as a basic sign of a 'scientific' discipline."

The tone and the tenor prefigures Partch thirty-seven years later, in the 1949 *Genesis of a Music*.

Sabaneev's emphasis on acoustics led him to the predictable end result: what he called "ultrachromaticism," today called just intonation.

Sabaneev advocated a radical move: throw away the 12-tone scale altogether. Ultrachromaticism was the music of the future; it lay outside the bounds of equal temperament, and the two could not coexist. Thus equal temperament must go.

In the overtone series, which he called "the basic consonant harmony," there could be no dissonances--only degrees of consonance. Sabaneev also predicted that ultrachromatic (or just intonation) music would use partials specifically adapted to the individual scale, resulting in what he called "harmony-timbres." **[Carpenter, 1983]**

This is a remarkably prescient suggestion. It anticipates James Dashow's seminal "Spectra As Chords" article by nearly a half century, and long predates John R. Pierce's *JASA* article and subsequent chapter (co-authored with Max V. Mathews) "Control of Consonance and Dissonance with Nonharmonic Overtones" **[von Foerster and Beauchamp, 1969]** as well as Wendy Carlos' article "Tuning: At the Crossroads" **[Carlos, 1987]** in which she explains how to eliminate beats in any tuning by tweaking individual partials.

Sabaneev was also a great admirer of the composer Scriabin. In fact he claimed to have traced the origin of Scriabin's "mystic chord" to the harmonics 1, 5, 7, 9, 11 and 13 of the harmonic series. This proved a controversial proposal (to say the least), since in standard Western music only harmonics 1, 2, 3 and 5 are tolerably well-represented.

In all of this Sabaneev's rival Avraamov dissented vehemently. Instead, he proposed what he called "omnitonality," a whole-hearted embrace of *all* equal temperaments.

During the year 1920-21 the Scholarly Council listened to forty lectures, nine of which were subsequently accepted for publication. Among these, four examined the topic of new musical tonal systems. E.K Rozenov talked about "The Basis for Establishing A New Tonal System," and "The Manifestation of the law of the Golden Section in Poetry and Music" (foreshadowing Thorwald Kornerup's proposals of the 30s and Jacques Dudon's article from "La Gamme Doree" in 1983); N.V. Petrov spoke "On the Basis for A New Tonal System." P.B. Renchitsky gave a talk "On the Question of Designating and Representing New Intervals Relative To the Expansion of the Sound System," and L. Sabaneev gave a lecture entitled "Ultrachromaticism." **[Carpenter, 1983]**

Some of these lectures dealt with what would today be called just intonation. "Ultrachromaticism" and "On the

Question of Designating and Representing New Intervals..." clearly concern ways of incorporating higher members of the harmonic series into music.

Western music stops dead at the 6th member of the harmonic series. But Sabaneev went much further--exactly how far, we can't be sure. From the size of the musical scales he advocated, however, it's possible that he may have advocated what Partch would call a 17-limit, or even a higher-limit, system.

In 1922 GAKhN (State Academy of Artistic Sciences) established a commission for the study of new scales. Sabaneev by this point was head of the Academy; but in 1923 both GIMN and GAKhN suffered an extensive reorganization. As a result much of the music theory research was now concentrated in a commission on acoustics, giving new leverage to the composers who advocated just intonation.

Garbuzov, now head of the commission, focussed his attention mainly on the acoustical foundations of traditional musical theory. (In effect, extending Rameau's work.) But besides Garbuzov's study, the acoustical commission continued to develop and evaluate new tonal systems, and this gave an opening to the equal-temperament composers, the proponents of "omnitonality."

Over 20 lectures on new musical systems were read at GIMN meetings. They included newly devised instruments and notations system. Each researcher adopted a differing system, but the battle lines were drawn much the same as they are today--between just intonation composers on the one hand, and on the other those interested in exploring equal temperaments outside 12.

Sabaneev lectured on the 53-tone equal-tempered system. Probably he settled on 53 as a way to approximate just intonation while overcoming the technical difficulties of building a just instrument that could modulate. Remember: in 1920, Lee de Forest's "thermionic valves" (*nee* vacuum tubes) barely existed. They were unreliable and costly. Many of the oscillator circuits common in today's textbooks had yet to be discovered in 1922-3. It would have been technically and financially impractical to build a fully retunable electronic instrument--requiring *hundreds* of vacuum tubes--with the equipment of the early 20s...and a purely acoustic just intonation instrument would have been limited to one key. Thus Sabaneev's 53-tone compromise.

Renchitsky investigated quarter-tones, along with new methods of notation and nomenclature; Leiberg proposed a forty-one degree tempered system and devised an instrument for it. Avraamov invented what he called the "Universal System of Tones." This was a forty-eight tone equal scale, a number he considered sufficient to reproduce all folk-song modes and "the timbral-harmonic complexes...familiar to inhabitants of the industrial centers of production." (This echoes to a remarkable degree Vicentino's advocacy of the 31-tone equal-tempered system in order to "accurately render the songs of all folk and every nation.")

Concerning this explosion of new tuning systems, Garbuzov concluded: "The work of A.M. Avraamov, P.B. Leiberg and E.K Rozenov has conclusively shown that it is possible to solve the problem of the expansion and transformation of the tonal system only with the aid of some form of equal-temperament (24- 41- 48- and 53-degree), and that pure tuning is technically unrealizable." **[Carpenter, 1983]**

In short, the exponents of non-12 equal temperament won the day.

This shouldn't be surprising. Precision frequency measurement was available only by analysing visual records made by instruments like the phonodiek, which scribed sound waveforms on a moving lampblack-coated glass plate with a vibrating needle. Nothing akin to a modern Peterson or stroboconn tuner existed. Oscilloscopes were unknown. There was no such thing as a precision temperature-controlled crystal oscillator frequency reference.

Given these disadvantages, it would have been nearly impossible to distinguish differences as small as 1/600 octave in the tuning of an instrument. But this is what true unadulterated just intonation calls for. In point of fact, the difference between the 700-cent tempered fifth and the 701.955-cent just fifth is 1.955 cents, ***less*** than 1/600 of an octave.

Given the crude electronics of the early 20s it's no surprise that just intonation fell outside the realm of musical possibility. Modulation between just arrays would have to wait fifty years, for the invention of the modern computer. (Even as late as 1939 an all-tube electronic organ, the Novachord, failed because of its complexity. With 171 tubes it proved too fragile and unreliable for a public used to sturdy pianos.)

Meanwhile, the first public demonstration and concert of quarter-tone music in Moscow was given in 1927 by Georgy Rimsky-Korsakov (the great composer's grandson), who was also the chief proponent of this music in Leningrad.

He continued his research into quartertone music and conducted a 24-tone ensemble from 1925 to 1932, along with other activities.

Around this time Russian musical life came apart at the seams. The Russian Association of Proletarian Musicians (RAPM) acquired total control of all musical activities. The predictable result: anyone who didn't agree with their radical

proletarian agenda was purged. **[Carpenter, 1983]**

Sabaneev's last notable microtonal article, "The Possibility of Quarter-tone and Other New Scales," was translated by S. W. Pring and appeared in *The Musical Times* on June 1, 1929. **[Mandelbaum, 1961]**

In 1929, GAKhN became GAIS, the State Academy of the Arts, subsequently moved to Leningrad. In 1931, GIMN was liquidated. RAPM advocated a simplistic music aimed at the masses. (Reminiscent of today's "Top 40s"--except that in 1920s Russia mindless lowest-common-denominator music was the outcome of Marxist-Leninist totalitarian state control, whereas in 1990s America mindless lowest-common-denominator music is the outcome of a glorious system of unfettered free enterprise.) Serious composers and music researchers were alienated by RAPM's agenda and musical experimentation ground to a halt.

Subsequent purges led to a dogmatic Marxist musicology, hostile to new ideas and "corrupting bourgeois capitalist influences."

Outside Russia, quartertones continued to grow in popularity throughout the 20s. A gusher of articles appeared: Sigmund Klein's "Quarter-Tone Data," in the *Pro Musica Quarterly*, March 1925, p. 21. "Some Quarter-Tone Impressions" by Charles Ives in the same publication, March 1925, p. 24. Alois Haba's "The Quartertone Problem," ("Kwart-tonen-problemen") in *De Muziek*, Amsterdam, 1927, p. 109. **[Mandelbaum, 1961]**

The 20s and 30s saw the most intense interest in quartertone composition throughout Europe and United States. In Italy during the 20s, Silvestro Balioni composed in quarter-tones; in Spain, Domingues de Burrueta and Panach Ramos; in France Marina Scriabin and Yvette Grimaud; and in America, Hans Barth, Mildred Couper, Henry Cowell and Charles Ives; and in Germany, too many composers to list. **[Asuar, 1957]**

After building a 24-tone harmonium in 1910, Jorg Mager switched to electronics in 1924 to escape the conventional 12 tone scale. In 1924 he penned the pamphlet *A New Epoch In Music through Radio*--in the 20s and 30s all electronics went under the cognomen "Radio" because the tubes used were designed for radio applications. This pamphlet appears to be the first document to detail the possibilities for new scales and new intervals offered by the new technology of vacuum tubes. In it he descibed a new instrument, the *sphaerophon*, and in 1925-26 he demonstrated the instrument in public. It was a crude tube-based electronic organ, one of the very first of its kind. Built specifically for quarter-tone music, the sphaerophon proved unsatisfactory. After two prototypes Mager built a larger and more complex device which he called the *partituophone*, which had several manuals, vibrato and "very advanced timbre controls." In 1931 the partiturophone was used to produce electronic bells sounds during a Bayreuth production of *Parsifal*. Tragically, Mager died in 1939 and his instruments were destroyed in World War II. His considerable achievements both as a pioneer of microtonal music and a trailblazer in the field of early electronic instruments have gone entirely unnoticed. **[Holmes, 1985; Mager, 1924]**

In 1928 Dmitri Levidis' *Symphonic Poem for Solo Ondes Musicales and Orchestra* premiered in France, using both quarter- and eighth-tones. The Ondes Martinot (as it was later called), like Theremin's Thereminvox, used beat oscillators; however the Martinot featured a pressure-sensitive keyboard and metal ribbon attached to the finger, allowing the performer to precisely gradate divisions of a semitone as well as controlling every nuance of the sound's amplitude envelope. **[Holmes, 1985]**

Not all xenharmonic currents swept in the direction of quartertones, however.

In 1927 one of the most far-reaching musical texts of the 20th century was published in Mexico: Augusto Novaro's *Sistema Natural Base del Natural-Aproximado*.

Novaro is a remarkable figure. "His theoretical dexterity," according to Ervin Wilson, "exceeds even that of Harry Partch." Novaro was the first theorist to discuss *every* equal division of the octave up to 31. He was one of the first to build instruments in a wide variety of tunings and actually *listen* to the resulting music. He was the first to suggest combining different equal temperaments. He was the first to re-fret guitars to a wide variety of different equal and just scales--not just multiples of 12/oct, but 15/oct, 17/oct, 19/oct, 22/oct, even 31/oct. **[Novaro, 1927, 1951]**

And in his 1927 text he discovered the principle of the tonality diamond--21 years before Harry Partch published it in the first edition of *Genesis of a Music*. **[Novaro, 1927]**

Novaro also defined the equal-tempered scale with the smallest number of tones capable of approximating the tonality diamond to a tolerable degree of accuracy--which turns out to be the 72-tone scale.

Thus Novaro's landmark 1927 text contains extensive information on 72-equal, as well as a just intonation overtone and undertone scale, long before Partch reintroduced just tunings into western music.

Why didn't Novaro's 1927 book have greater impact?

Hard to say. Perhaps because it was self-published in an extremely limited edition. Or perhaps because the Mexican revolution had created bad publicity that smacked of the "pinko Red stuff" going on in Russia. Perhaps because Carrillo

was a brilliant performer and composer: his orchestral works were championed by Stokowski. Novaro's largely theoretical texts must have seemed etiolated by comparison. And there was a general contempt in musical circles for anything not central European in origin.

In any case Novaro's book was never translated into English. Diagrams of his 72-tone harps and re-fretted guitars went unnoticed.

Carillo is a well-known figure in the history of microtonality, and his place as a composer is secure. His influence on the French microtonal movement of the 50s and 60s was considerable; and no wonder. Carillo was a tireless promoter with a genius for publicity, and had important connections in the Mexican government. His influence was such that he was able to induce a German piano manufacturer to build 16 specially-designed pianos: one each in 18/oct, 24/oct, 30/oct, 36/oct...96/oct. **[Carillo, 1924; Wilson, personal communication]**

Anyone who understands the 25 tons of stress on a cast-steel piano frame generated by the complex cross-arrangement of piano strings wired to an overlapping pattern of pins and anchored pinblocks knows that building a 96-tone piano is a *huge* technical accomplishment--but its musical value is another question.

Carrillo's 16th-tone piano had 96 keys instead of 88. Its compass was limited to the single octave around middle c. It used the standard keyboard, as did all his specially-built pianos.

Carrillo composed some music for his 18-tone and 96-tone microtonal pianos, featured in *Balbuceos*. Alas, mesmerized by divsions of the 6-tone scale he completely overlooked the equal divisions of the octave most vividly different from12: namely, 15, 17, 19, 22, 25, 27, 29, 31, 33, 37, 41, 43, 46, 51, 53, ad infinitum.

Why did Julian Carrillo restrict himself to subdivisions of the whole-tone scale?

It's impossible to be sure.

One could argue that the motive was sheer expediency. It's relatively easy for musicians to divide a semitone into 2 equal parts. Far easier, surely, than asking violinists or French Horn players to divide the semitone into multiples of 12/41!

But this can't be entirely correct. Carrillo wielded enough influence to have a set of microtonal pianos made. So he could obviously have had those pianos tuned to *any scale he chose*--and a 19/oct piano would have been infinitely more interesting than a 48-tone piano (which can be had simply by wheeling 4 concert grands together and tuning each one 1/4 of a semitone apart).

No, the only reasonable answer is that Carrillo simply *did not realize the advantages of moving outside 12.* His set of unique pianos, impressive as technical curios, don't lead us outside the 12-tone scale. They merely subdivide 12--cutting each semitone into 2, 3, 4 and more parts.

But the essential structure of the 12-tone scale remains. Its symmetry, its limited set of consonances, its characteristic fifth...none of this ever changes. Even in 96-tone we are still stuck with *exactly the same fifths* available in 12.

Carrillo never made the leap. Nor did he concern himself with just intonation. However, he ***did*** build harp-like a kiathara-like instruments in up 96 tones/oct, along with guitar-like instruments, though he did not build metallophones or ideophones. He also trained an ensemble to play in non-12-tone systems--the first of its kind. The earliest recordings of Carrillo's microtonal works date from the 1940s, and may have proved an inspiration for Partch's ensembles. **[Carillo, 1924]**

Carrillo's excellent *Dos Bosquejos*, his *Balbuceos*, his *Preludio A Cristobal Colon*, and many other compositions have notably enriched the microtonal literature. But how much more influential would Carrillo have been if he had composed in completely non-12 scales?

We can only guess.

Then there is the matter of his musical writings.

Augusto Novaro's books have aged well. Not so Carrillo's.

In February 1924 his *El Sonido 13* ("The Thirteenth Sound," originally a set of newspaper editorials) was published in a revised hardbound limited edition. Consider the following sample:

"*We are about to see the accomplishment of the greatest transcendence that has taken place since before the time of Christ...the psychological transformation produced by Christian doctrine was surely no greater than the formidable revolution which 'The thirteenth sound' will produce in the art of tones.*" (*El Sondio 13*, 1924, page 6.)

Carrillo ***did*** excel in composition. He also introduced a remarkably useful form of musical notation which did away with conventional staff-lines and replaced note-heads with numbers. Carrillo's notation, originally suggested (but discarded) by Luigi Russolo in 1914, has several disadvantages but it remains one of the few systems applicable with equal fluency to ***any*** possible equal tuning.

His *Preludio a Cristobal Colon*, which John Chalmers has aptly described as "almost supernaturally beautiful," remains a classic. It was later printed (using Carrillo's unique and extremely useful numerical notation system) by *New Music*

Editions in 1939.

Along with Mexico, the major centers of microtonality in the late 1920s and early 1930s were America, Denmark and Germany. Thorwald Kornerup and Joseph Yasser were the dominant figures, along with J. Murray Barbour, whose doctoral thesis gave the lie to the popular wisdom that (as Leonard Bernstein so incorrectly stated) "These are the 12 tones nature gave us." Barbour's book looked backward, but still gave tremendous historical ammunition to the advocates of just intonation and non-12 equal temperaments. **[Barbour, 1951]**

In Czechoslovakia Franz Weismayer also composed quarter-tone works during the twenties. **[Mandelbaum, 1961]**

Germany was the most active site of musical innovation throughout this period. Many Germans composed in the 24-tone system, while another rival group extolled the virtues of the 19-tone system. Alois Haba's opera, *Die Mutter* (The Mother), was produced to great acclaim in Munich in the late 20s. The opera is a breakthrough: it calls for a a complete complement of quarter-tone instruments, including a string section, a pair of 24-tone clarinets, a pair of 24-tone trumpets, 2 slide trombones, a quarter-tone piano, a quarter-tone harmonium and 2 harps tuned a quarter-tone apart.

Haba's *Neue Harmonielehre* was published by F. R. Kistner and C. F. W. Siegel, Leipzig, in 1927. By comparison with Novaro's groundbreaking text, the Haba book offers little new: it begins with a standard discussion of the possible scales in traditional 12/oct. Then he branches out to a discussion of the 24-tone temperament and then 36-tone equal temperament. Finally, he takes up 72-tone, which combines all the possibilities of each of the other 3 systems considered. However Haba does not attempt to take any special advantage of 72's remarkable acoustic advantages, as Novaro does in approximating the pitches of his just tonality diamond. **[Mandelbaum, 1961; Chalmers, 1992]**

Nor did Haba greatly concern himself greatly with novel systems of notation. He uses eleven different kinds of sharp signs to provide for every possible tone between the whole-tones of the 72-tone system.

Interestingly, Haba isn't dogmatic about exact equal temperament at all times. In the introductory notes to his *Music for Unaccompanied Violin*, Opus 96, he states that he considers the quarter-tones roughly even subdivisions of the semitones *as they are normally played on the violin*. But since violin players tend to *sharp* chromatic notes which resolve *upward* and to *flat* chromatic notes resolving *downward*, this means that the performer will be playing chromatic and diatonic semitones of different sizes, and will have to estimate the relative size of a quarter-tone jump by ear. **[Mandelbaum, 1961]**

This is a refreshing change to the usual doctrinaire requirement of perfectly exact tuning--in Partch's case, the ludicrous statement that a tuning discrepancy of 2 cents is unacceptable. (The human ear is incapable of perceiving melodic jumps of less than 6 cents in a musical context. Even if tones are sustained for a long period, a tuning error of 2 cents is easily swallowed up by the slightest vibrato, chorus effect, or reverberation.)

Presumably, Haba's casual attitude toward the size of quarter-tones on an unaccompanied violin tells us that he was more interested in getting a xenharmonic effect--i.e., a melody or harmony that sounds noticeably differently from standard 12/oct western music--than in precise quarter-tones *per se*. **[Mandelbaum, 1961]**

Germany contained more than one xenharmonic current, however. In addition to Haba's traditional and fairly unadventurous subdivisions of the 12-tone scale, there arose at least one advocate of a completely non-12 tuning.

The German theorist Jose Wurschmidt issued a number of pamphlets and articles starting in 1920: "The Logarithmic and Graphic Representation of Musical Intervals," *Zeitschrift fur Physik*, III, p. 89 (1920), "The 19-Tone Scale," *Neue Musik-Zeitung*, XLII, p. 215 (1921), "The Rational System of 24 Steps Per Octave," *Zeitschrift fur Physik* XLII, p. 1893 (1921) and "Quarter- and Sixth-Tone Music," *Neue Musik-Zeitung* XLII, p. 183 (1921). He suggested a group of non-12 scales which Jospeh Yasser and Thorwald Kornerup would later take up in their more extensive writings during the 30s. **[Wurschmidt, 1920, 1921; Mandelbaum, 1961]**

Wurschmidt's discussion of the 19-tone and 31-tone systems is remarkable: during this period most musicians interested in new tunings had settled for the easiest and most expedient avenue: dividing the 12 semitones into 2, 3, or more parts. A 19- or 31-tone system would have required entirely new instruments--and would have made possible entirely new harmonies, quite outside of the traditional 12-tone system. **[Mandelbaum, 1961]**

In 1925 the 19-tone scale gained more support when the pseudonymous German author Ariel published an entire book extolling the enneadecaphonic system.

The text is striking because, again, it posits a complete break with 12.

Called *Das Relativitatsprizip der Musikalischen Harmonie* ("The Relativity Principle of Musical Harmony"), it was published by the start-up press Neuzehn Stufen Verlag. A second volume, promising details of a 19-tone keyboard instrument, was never published. Neither was the putative third volume, which was to have provided exhaustive acoustic information on 19. **[Mandelbaum, 1961]**

Das Relativitatsprizip is the first in a long line of violent 20th-century polemics favoring other scales and condemning

12-tone equal temperament. The author distinguishes himself early on as an implacable foe of the 12-tone system. It wasn't enough merely to try 19: the 12-tone scale had to abandoned as well. And Ariel's arguments are in other ways reminiscent of Partch's: that consonances should be as pure as possible, that the scale should have intervals much smaller than 1/12 octave, that it differentiate clearly between consonance and dissonance, *und so weiter.*

These notions are peculiar in light of the fact that Ariel is dealing with a tempered scale. One would expect *any* tempered scale to be disqualified by *any* of these criteria--particularly 19.

A composer who craves pure consonances would clearly be better off moving to just intonation. Just arrays also offer a limitless wealth of small intervals--commas of many different kinds, as small as 1/53 octave or smaller. And just scales vastly surpass their tempered kin in distinguishing between consonance and dissonance.

But Ariel's arguments for the 19-tone scale are peculiar even within the restricted compass of equal temperament.

The 19-tone fifth, for example is 1/170 octave out of tune with the third harmonics. By contrast, the 12-tone fifth is only 1/600 octave out of tune. So his first criterion actually favors 12 for fifths. The major third in 19 is slightly closer to the 5/4 than 12's major third, but the real winner is 19's minor third, less than .1 cent off from the 6/5.

But only statistical legedermain allows 19-tone to win over 12 as far as "pure consonance" is concerned. The 19-tone system has a smaller sum-of-squares residue *vis-a-vis* the 4:5:6 triad than does 12... But so what? The ear does not hear squared sums of cents: it hears *beats*, which are not well-represented by the statistician's beloved variance.

As for the second argument, 53-tone or 118-tone are demonstrably far superior to both 19 and 12. So this criterion actually militates *against* both 19 and 12.

And since all equal-tempered systems deliberately blur the distinction between consonance and dissonance by slightly (sometimes grossly) detuning both consonances and dissonances, Ariel's third argument again points toward 53- 65-, 72- or 118-tone equal temperament as the closest approach to a just system.

A subsidiary justification for 19 comes from Ariel's requirement that an ideal musical scale possess three "constructing intervals." The root, the third and the fifth are so defined; subsequent accounting tricks lead to a set of five intervals which all "good" scales should approximate. But again it's not clear why good scales should have only three constructing intervals: in fact, this requirement contradicts Ariel's demand for pure consonances. A good approximation of the just seventh would produce a fourth "constructing interval;" ditto a near-just-11th, and so on.

In short, Ariel's reasons for advocating the 19-tone equal-tempered scale appear to be a smoke screen. It is likely that he simply favors the system, and after having settled on 19 he subsequently cooked up supporting criteria.

Like most of the other theorists of his day Ariel engaged in an ardent musical witch hunt, avidly dividing musical scales into "good" and "bad" groups. The "good" groups were those that fit into a quasi-Fibonacci series similar to Yasser's: 7, 12, 19, 31, 34, 53, 65, 118, 171, 289, 323, 441, 612, 730, 1053, and so on. The "bad" systems were basically any scales missing from the musical crossword puzzle.

He eliminates from consideration such excellent scales as 9/oct, 10/oct, 15/oct, 17/oct, 22/oct, 27/oct, 29/oct, 33/oct, 41/oct, 55/oct, ad infinitum.

It's unclear whether Ariel heard much (if any) music in the 19-tone system. He may have tuned a harmonium to the scale: the advertisement in the back of his book touts a second (forthcoming) volume with details of a 19-tone organ. The second volume never appeared.

Germany's hyperinflation would likely have killed off Ariel's publishing house even without help from his prose. But the author's polemical bent, his reliance on dubious (occasionally mystical) number-games, and his lack of verifiable experience in composing and listening to 19-tone music (or any other non-12 equal temperaments)didn't help *Das Relativitatsprizip*.

Nonetheless, the book remains significant for at least one reason: it boldly suggests a step completely outside the 12-tone system rather than a simple subdivision of the 12/oct semitone.

For this reason (if for no other) Ariel must be considered a major figure in the history of microtonality and the premier exponent of the 1920s German 19-tone movement.

The other two major figures of this period produced their central work during the 1930s.

Joseph Yasser's book *A Theory of Evolving Tonality* has proven influential for more than half a century. Ervin Wilson has stated that he took the inspiration for most of his work from Yasser; John Chalmers and Ivor Darreg have repeatedly either reacted against or composed music in accordance with Yasser's prescriptions. And simply as a sourcebook detailing properties of the 19-tone scale, *A Theory Of Evolving Tonality* will remain valuable even in the 21st century.

Yasser actually heard the 19-tone system. He used two pianos in proximity to obtain a complete 19-tone scale, and according to Kenneth Gaburo, Yasser composed a 19-tone piece for strings during his (Yasser's) student days. **[Burt;**

personal communication; Chalmers, personal communication]

One of Yasser's cleverest inspirations was to switch the argument for 19 from acoustic to historical-determinist grounds. This must have seemed a particularly compelling thesis in the 1930s: even as Communism seemed to be sweeping across the world, fueled by a doctrine of inevitable socioeconomic progress, the idea of fitting a Fibonnaci series of scales into a similar Hegelian determinist system doubtless seemed irresistable.

According to Yasser, music evolved from 5-tone scales and proceeded to 7. It then developed by adding the previous 5 to the 7 tones and obtaining 12. The next step in the inevitable progression is, of course, 19.

Good acoustics are one thing--but when you've got the force of historical necessity behind you, how can you lose?

Yasser's book carries real weight not only because of the socio-historical notion of scale development, but also because it makes the diatonic argument for alternative scales with particular cogency. (A line of reasoning followed to different conclusions fifty years later by Easley Blackwood in his *The Structure of Recognizable Diatonic Tunings*.)

According to Yasser, the ear perceives musical notes according to their function within the scale, rather than their mere Fourier sum. He defined an abstract principle of "diatonicity" according to which some scales were favored over others.

The basic idea was this: since the 12-tone scale features 7 diatonic steps in the familiar major or minor scale, Yasser posited that the 19-tone scale would feature 12 diatonic steps for its ultra-major or ultra-minor scale.

Influenced by the historical determinist doctrines of the day, Yasser presumed that all music would universally advance from one member of his Fibonacci series of scales to the next. To bolster this notion he traces the evolution of musical system with smaller numbers of tones than our own.

Yasser did not give much attention to useful systems not present in his Fibonacci series of scales--14, 15, 17, 22, etc.

But the train starts to run completely off the tracks when Yasser derives consonant chords in the 19-tone system. Logic would suggest a root, a third and a fifth; but this was apparently too straightforward. Instead, he posits as the basic vertical structures of the 19-tone system a set of hexads generated out of what he calls "supra-thirds" (3/19 and 4/19 of an octave).

Accordingly he labels as consonances 3, 4, 6, 7 and 9 nineteenths of an octave, along with their inversions. But he labels as dissonances what sounds like a major third and a perfect fourth (5/19 and 8/19 of an octave) and a perfect fifth (11/19 of an octave)!

The ear hears as its two *purest consonances* the scale-intervals which Yasser labels *dissonances*.

Despite this gaffe, Yasser's work retains a good deal of influence today. It is particularly impressive for its careful, scholarly discussion of the evolution of musical scales. While the details of Yasser's hypothesis may be suspect, the general idea that musical systems are not etched in granite, and that they change and evolve over time, is invaluable for understanding the music of our own culture--as well as others.

His careful examination of the properties of the 19-tone scale is also invaluable. As long as the prospective xenharmonist takes Yasser's definitions of consonance, dissonance and hexads with several metric **tons** of salt, *A Theory Of Evolving Tonality* offers useful information.

Thorwald Kornerup is the other major figure in alternative tuning in the 1930s. Although his first pamphlet, *Musical Acoustics Based On the Pure Third System*, appeared in Copenhagen, Denmark in 1892, the rest of his work was done between 1930 and 1938.

His early writings staunchly defend the "small" fifths of the 19- and 31-tone equal tempered systems. The fifths are an advantage, he claims, because they make possible the purer thirds available in these systems and not in 12/oct.

Like Yasser, Kornerup thought that good musical scales proceeded from three generating intervals: the 2nd, 3rd and 5th members of the harmonic series. This leads to what is today called a 4:5:6 triad, or an approximation thereof. (As for approximations of 3:5:7 triads, 5:7:11 triads, etc., like all other writers of this period Kornerup does not consider the possibility.)

Because no power of 2 is ever equal to a power of 3, any relationship between the 2nd, 3rd and 5th harmonics must spiral around a circle of fifths (or thirds) without ever returning to the original pitch. To force the circle of fifths (or thirds) to meet, equal temperament must bend the 3rd and 5th harmonics out of tune. In an equally-tempered scale, they can only be approximations.

But this disturbed Kornerup because he wanted a universal basis for measurement. He was looking, in short, for a means of discovering which tunings were "right" or "wrong" without recourse to the traditional measures of "farther from 12" or "closer to just."

His solution was the golden ratio, 1.618304.

The algebraic definition of the golden ratio is : a/b = b/(a+b) or more simply as $k^2 - k - 1 = 0$ where k = a/b.

Kornerup asked: what kind of scale do we get if the chromatic and diatonic semitones differ by ratio k? The result gives a = 73.5 cents and b = 118.9 cents. The just value for the chromatic semitone is 70.7 cents (25/24) and the just diatonic semitone is 111.7 cents (16/15), so his results fall reasonably close.

A + b = 192.4 cents, a + 2b = 311.4 cents, 2a + 3b = 503.8 cents, and so on. The relationship between successive intervals remains: chromatic semitone/diatonic semitone = diatonic semitone/ton = tone/minor 3rd = minor 3rd/perfect fourth = 0.618304.

Adding all these intervals produces a perfect 2:1--that is, an octave.

Kornerup claims that this "golden system" is a universal yardstick by which all musical scales can be gauged.

But why is this system superior to the harmonic series or the idea of an abstract diatonic scale? Kornerup does not answer this objection. Perhaps he was looking forward to the day when composers could detune each harmonic to suit the scale in which they worked.

As a musical system, the "golden scale" is enormously important. It's the first example in the microtonal literature of a vast universe of scales which are only now being explored: the non-equal-tempered, non-just scales.

Kornerup's golden system is also closely related to the Fibonacci series of equal temperaments (5,7, 12, 19, 31, 50, 81, 131, etc.) because successive terms in the Fibonacci series tend to approach the golden ratio (.618304). So Kornerup by default becomes an exponent of the virtues of this particular group of scales, and as in Yasser's evolutionary theory, the differences between the golden values and the equal-tempered scale values approach zero as the number of tones in the series grows large.

Again, it is unlikely that Kornerup built instruments in any of these systems, or that he composed music in any of the Fibonacci series of temperaments he advocated. Like Ariel and Yasser, he leaves out important equal temperaments (17, 22, 33, 37, 41, etc.) for no obvious reason other than numerology.

Withal, his work remains important for three reasons: he gave an additional justification for exploring Fibonacci group of tunings 12, 19, 31, 50, 81... none of which are subdivisions of 12/oct; he was the first to define and examine a series of non-just,non-equal tunings; and his search for a universal measure for tuning systems prefigures that of many other later writers--specifically, Partch, Darreg and particularly Wilson.

REAL INSTRUMENTS AND REAL MUSIC: 1940-1960

While the 1920s and 1930s belonged to quarter-tone composers and theoreticians, the next period in microtonality was dominated by composers and instrument-builders.

In 1941 Tillman Schafer presented to the Division of Mathematics and Natural Sciences at Mills College a thesis entitled *The Music Of Tomorrow: The Supra-Diatonic Scale, A New Concept of Timbre; The Electronic Musical Instrument.*

This document summarizes Yaaser's writings and goes on to detail Schafer's construction of an actual electronic instrument capable of playing 19-tone equal temperament. Together with James Piehl, Schafer built several 19-tone instruments, including a 19-tone reed organ with tracker action (not an harmonium) and a 19-tone guitar. **[Wilson, personal communication; Darreg, personal communication; Chalmers, personal communication; Mandelbaum, 1961]**

The "electronic" component of Schafer's 19-tone instrument consisted of a set of solenoids actuating hammers that struck specially-shaped metal bars. The bars were so milled as to eliminate the 3rd and 6th harmonics from their timbre. This was recommended by Yasser, who (as we've seen) considered the 19-tone approximation of the 3rd harmonic a dissonance. Shafer kept the instrument at the Naval Electronics Laboratory in San Diego and part of it still exists. (In later years the solenoids corroded and the metal bars were given to Ivor Darreg and subsequently to Buzz Kimball.) **[Darreg, personal communication; Kimball, personal communication]**

Schafer also tuned up a set of vacuum-tube oscillators during WW II and experimented with 50-tone note-clusters (also in accord with Yasser's Fibonnaci progression of scales), generating unique and remarkable musical effects.

In 1947 Schafer presented a a report to the Acoustical Society of America in which recordings of music by Scriabin and others were played in the 19-tone scale. Here, for perhaps the first time, we see traditional 12/oct music being translated into and actually *performed* in a **completely** non-12 scale. **[Mandelbaum, 1961; Darreg, personal communication]**

In France, Alain Danielou published a text which describes and categorized a vast number of different just-intonation ratios. **[Danielou, 1947]**

Esther Tipple and Royal Merrill Frye tried to popularize 53-tone equal temperament using another approach: they

built an instrument which they called the *harmon*, and in the middle 40s sent out a good number of charts and diagrams demonstrating the advantages of 53. Unfortunately their silent diagrams had less effect than actual music would have had--but at the time, high-quality tape recorders were unknown in the U.S. Only impossibly poor-quality wire recording machines were available, and those cost fabulous sums. **[Mandelbaum, 1961; Darreg, personal communication]**

Meanwhile, isolated in Estonia, the composer and theorist Jaan Soonvald developed his own just intonation system. Like the Soviet composers of the 1920s, Soonvald was brutally suppressed by the *apparatchiki* of Estonia's post-war Communist puppet state. Only recently has Soonvald's remarkable contribution been brought to light. **[Rais, 1991]**

Yasser's influence continued throughout the 1940s. In 1944, the acoustician Robert W. Young wrote "Some Problems of Postwar Musical Acoustics." (*Acoustic Society Journal*, October 1944.) Among the ten most challenging problems for musical acoustics, he listed a practical test of Yasser's theories. **[Young, 1944]**

In the Netherlands during WW II the physicist Adriaan Fokker rediscovered the 31-tone scale. 31 had originally been championed by the 17th-century Dutch scientist and harpsichordist Christiaan Huygens, in his paper "A New Harmonic Cycle." Faced with Nazi occupation of the Lowlands, Fokker devoted himself to studying the Huygens 31-tone scale and quickly developed an entirely new notation for it. **[Fokker, 1966]**

After the war, he devoted himself entirely to music. Initially interested in just intonation, Fokker hit ont he 31-tone scale as the best compromise for approximating just ratios with an equal-tempered scale. In 1960 Fokker established the Stichting Nauwluisterendheid (Foundation for Listening Accuracy), later renamed the Huygens-Fokker Institute, and recruited a large and active group of superb 31-tone instrumentalists: the most important of these were surely the violinists Lemke and Vos. An excellent cadre of composers also gathered around Fokker; most notably Jan van Dijk, Hans Kox and Anton de Beer. Throughout the 1940s and 1950s Fokker published a number of influential papers advocating the 31-tone system, as well as composing many pieces in the system.

In 1950 he designed and obtained the financial backing to build the first modern 31-tone organ--the first of any description, in fact, since Vicentino's Archiorgano in the 17th century. Called the "Fokker organ," it featured two Bosanquet-style generalized 31-tone manuals and a pedalboard. The first concert with the new organ was given on 10 September 1951, featuring compositions by Jan Pieterzoon Sweelink, Paul Christiaan van Westering and Jan van Dijk. 31-tone organ concerts took place frequently from 1951-55, featuring both new 31-tone music and arrangments of 12-tone classics.

It's important to note that many of these pieces were also ***performed*** by quartets and other Netherlands ensembles during his lifetime. **[Rasch, 1987]** Fokker's compositions weren't just "music for the eye." His efforts produced an active, ever-expanding xenharmonic community in the Netherlands centered around the 31-tone scale. **[Fokker, 1966]**

Fokker also came up the idea of ratio space--that is, a geometrical space in which the coordinates represent intervals by mapping out the approximated ratios of a non-12 tuning. (Erv Wilson later extended this concept to great effect by applying the idea to combinatoric structures, in which the coordinates represent abstract combinatoric dyads.)

One of Fokker's more widely-publicized articles in English dates from 1951. "A 31-Tone Instrument" in The Scientific Quarterly (1951), combines arguments for the "tricesimoprimal" system (as he called it) with explicit scale-degree-space diagrams of the scale's virtues and pictures of the Fokker 31-tone organ, now installed in the Teylers Museum [Fokker, 1951; Rasch, 1987]

The *Archifoon*, a second more advanced 31-tone electronic organ built in 1970, has also had a long life, prompting Joel Mandelbaum and others to write a number of compositions for it.

Fokker's seminal 1966 book *New Music With 31 Tones* (translated into English by Leigh Gerdine) sums up a lifetime of xenharmonic exploration.

Because of the high quality of his compositions, his continuing contributions to just intonation theory, the enormous influence of the Huygens-Fokker Institute, the superb cadre of 31-tone performers and composers he gathered and encouraged, and the lasting impact of his writings, Adriaan Fokker surely qualifies as one of the most important microtonalists of the 20th century.

By far the most influential figure of the 1940s and 1950s, however, was Harry Partch.

After encountering a copy of the Helmholtz-Ellis text *On the Sensations of Tone* in April 1923, Partch had begun to think of music in terms of ratios. The first draft of his theoretical treatise "Exposition of Monophony" (now lost) was completed in San Francisco in May 1928 and in October 1930 he finished his final draft. By this time he had already decided on his 11-limit just musical system. (His early work used a 29-tone just scale, which he called "the 29 tones within 11.") **[Mayfield, 1930]**

His just scale metamorphosized between 1930-1935, as did his terminology. Apparently he had not yet discovered the

Tonality Diamond (the members of his scale listed as a symmetrical harmonic and subharmonic array) nor had he settled on a fixed language to describe his system.

By 1931 he had completed his Adapted Viola (a discarded cello fingerboard marked with the 29 just intervals of his scale and attached to a lengthened neck which was then joined to a viola body) and in London in 1934-5 he built a just reed organ, which he called the Ptolemy. **[Gilmore, 1993; Partch, 1935]**

But he didn't arrive at his full 43-tone scale nor did he start to amass a full home-built orchestra of hand-carpentered instruments until the early forties. The first edition of *Genesis of a Music* dates from 1947; and his Gate Five ensemble did not exist until the early fifties.

Partch's contributions were fourfold:

First, he proved that a composer could attain recognition even after throwing away the conventions of western music and taking an entirely different path.

Second, Partch's music is vivid, powerful and distinctly xenharmonic. It does not sound like anything produced by Europe in the nineteenth century, yet people enjoy it.

Partch's third contribution lay in reintroducing just intonation to western music, and in building and tuning a set of just instruments that made actual music.

By violating every post-1650 convention of western art music and making a reputation in the process, Harry Partch established himself as a role model for subsequent xenharmonic composers. His success in forcing alternative tunings into the concert hall can't be underestimated. Many xenharmonic compositions would not today be considered by serious ensembles if Partch had not first shown that it was possible.

Partch's music is generally excellent. Some ("Plectra and Percussion Dances," "And On the Seventh Day Petals Fell In Petaluma;" "Two Studies on Ancient Greek Scales") is instrumental, while the vast bulk uses choral performers who both play the instruments **and** intone a libretto in a manner reminiscent of *sprechgesang*. **[Partch, 1949]**

Partch's fourth contribution lay not just in his rediscovery of just intonation, but in the definitions and classifications he invented to describe just scales.

He was the second theorist (after Augusto Novaro) to discover the principle of the tonality diamond--and he was the first composer to put it into practice (on his Diamond Marimba, among other instruments). Partch was the first theorist to define "5-limit," "7-limit," and other "limit" intonations. He was the first to point out that 12-tone equal temperament approximates a 5-limit just array. He was the first to build instruments and compose music that accepted the 7th and 11th harmonics as consonances. **[Partch, 1949]**

He was also the first xenharmonic composer to train a cadre of musicians to perform just intonation music in a disciplined ensemble. And in fact only Carrillo had successfully trained an ensemble to perform large-scale microtonal compositions before Partch.

Many of the Partch performers have gone on to produce important work themselves. Jonathan Glasier, Dean Drummond and David Doty have all built home-carpentered instruments and continued Partch's tradition.

Partch's recordings from the 1950s and 1960s have also influenced generations of listeners.

Clearly, Partch is the dominant composer and instrument-builder of the period.

The last Russian theorist and composer to extend the frontiers of microtonality was Aleksei Stepanovich Ogolevets.

His book *Foundations of Harmonic Language* was published in 1941. Totalling 970 pages, the tome explores in detail not only conventional harmony but also expanded tonal systems, including the 17- and 22-tone equal-tempered scales. The range and breadth of Ogolevets' discussion surpasses anything published in the USSR. Unfortunately WWII forced him to temporarily shelve his xenharmonic explorations. **[Ogolevets, 1941; Carpenter, 1983]**

His subsequent 1948 text *An Introduction to Contemporary Musical Thought* contains an extensive discussion of the 17-tone and 22-tone equal-tempered scales, along with a variety of other tuning systems. Ogolevets goes on to propose that musical history can be divided into four periods, with current events sweeping us from the third toward the fourth epoch: in the third era of music, he contended, a single system (the 12-tone equal temperament) would dominate, while in the fourth era the 17- and 22-tone scales would be widely adopted. **[Ogolevets, 1948; Carpenter, 1983]**

Ogolevets' thesis was a bold jump. Some would even argue that he was on the money--that music literally *was* in transition from the third to the fourth epoch at the time he wrote his book.

Regardless, his tome was singled out for brutal attack by the Zhdanov stooge Tikhon Khrennikov, at that time head of the composers' union and the main speaker at the infamous 1949 meeting of the Composers Union. An "example" was made. Ogolevets was ridiculed when he appeared at the conference in an attempt to explain himself. **[Carpenter, 1983]**

Other composers and theorists got the message.

Very little microtonal work appeared in the U.S.S.R. from 1948 until the present time.

In the west, however, xenharmonic explorations continued apace.

Norwegian composer Eivind Groven issed the book "Equal Temperament and Pure Tuning," advocating just intonation, in 1948. He built a second more elaborate just intonation pipe-organ in 1954, an instrument with one stop and 36 pitches per octave. In 1965 he applied electronics to the problem and built an electronic just intonation organ with 43 pitches per octave and 33 stops.

Starting in 1950 the French composer Jean-Etienne Marie "has been engaged in research on instrument construction in order to obtain new sounds [*sic*], particularly micro-intervals." **[Grove's Musical Encylopedia, entry for Marie]** He founded the *Centre International de Recherches Musicales* in 1968 and his *Tombeau de Julian Carillo* from 1966 is written for two pianos, one of them tuned in third-tones, while his *Ecce ancilla Domini* is based on a quarter-tone row. He was also the driving force being CIRM's construction of synthesizer to produce precise quarter-tones. His 1970 *Hommage a Jean-Pierre Guezec* for tape employs a 5th-tone harp, likewise building on Carillo's heritage.

Another ORTF *Groupe de Recheres Musicales* member, Claude Ballif, completed a theroetical treatise *Introduction a la metatonalite* in 1953; the work was published in 1956 with a foreword by the aesthetician Etienne Souriau. In 1972 the proceedings of a symposium on 'ultrachromatic' music, edited by Ballif, appeared as *Nicloas Obouhew et Ivan Wyschnegradsky*. Ballif was appointed professor of analysis at the Paris Conservatoire in 1971.

Ballif's metaonality, based on a scale on 11 notes, extends and systematizes the early 'free atonality' of Schoenberg--but Ballif's work also includes occasional use of quartertones, as does Pierre Boulez's 1946 composition *Le Visage Nuptial*, based on 2 cotemporal 12-tone rows in a single quartertone scale. (According to Mark Lindley's and Paul Griffiths' article "Microtone" in *Grove's Encylopedia*, this latter is the first quartertone serial composition.) **[Marie, 1983; Grove's Musical Encyclopedia entry for Boulez]**

As early as 1890 the Australian Percy Grainger had aimed toward what he called 'free music,' a music of sine waves in which amplitude, pitch and spectral density all gradated continuously--a sharp break with the discrete pitch-steps and timbral blocks favored by traditional Western music.

From 1950-51 Percy Grainger and Burnett Cross built an analog synthesizer programmed by flexible cardboard rolls on which graphs had been inscribed to control volume, timbre and tempo. Around the same period Grainger had a small piano and subsequently a reed box tone-organ built and tuned to the 36-tone system. Grainger made groundbreaking recordings with his 36-tone piano using the *vorsetzer*, an early velocity-sensitive player-piano-type system; this is perhaps the first recorded example of a composer using an automated performance system to transcend the keyboard limitations imposed by a scale with many equal steps per octave. **[reference to be added with Burt's xerox]**

Also in 1951 James Murray Barbour's book *Tuning And Temperament* appeared. Originally a 1932 doctoral thesis, Barbour expanded it until it became an astonishingly exhaustive catalogue of early xenharmonic musical experimentation. Chapter six, "Multiple Division," clearly inspired both the title and much of the subject matter of M. Joel Mandelbaum's breakthrough 1961 thesis *Multiple Division Of the Octave and the Tonal Resources of the 19-Tone Equal Temperament*.

Barbour's discussion of early just intonation systems provided fuel for the growing just intonation movement; here, in a single text, just enthusiast found a stunning array of early just systems. No one who read the early section of Barbour's text could pretend that 12 equal steps was the only division musically practical or possible; but Barbour's "Multiple Division" chapter also exhaustively chronicled the advantages and disadvantages of a vast number of previously-neglected equal temperaments.

However, in Donald Hall's words, "*...we must reexamine Barbour's approach. He seems strongly oriented toward presenting equal temperament as the ultimate solution to the tuning problem, one that makes all others of little more than historical interest. Specifically, he seduces the unwary reader's judgment by using the equal-tempered scale as a yardstick.*"

To contemporary eyes Barbour's book also relies excessively on baroque mathematical procedures: binary continued fractions, obscure numerical series, the "Golden Ratio," and other quasi-mystical constructs whose application to music is of dubious utility. It's easy to forget that in 1932 (or even 1951) the slide rule was still was the only way of rapidly multiplying or dividing floating-point numbers. Tables of logarithms were still widely used for multiplication and division--digital computers were *far* out of reach for the ordinary music theorist.

Today, with personal computers and hand calculators, it seems weird that Barbour spends page after page discussing this or that arcane mathematical method of deriving 43-tone or 53-tone equal temperament: why didn't he simply print out all the intervals of all the equal-tempered scales and examine them?

Given the technology of 1932 or 1951, this wasn't practical. More: tables of hand-calculated scale degrees were prone to error propagation. So Barbour's seeming obsession with odd mathematical nooks and crannies becomes more com-

prehensible--though still largely useless to today's xenharmonist.

Notably, Mandelbaum's thesis bypasses entirely the strange mathematical procedures that characterize Barbour's book.

Although he came down lopsidedly in favor of equal temperament, Barbour's encylopedic reference became a touchstone of *both* the just intonation movement *and* the advocates of xenharmonic equal temperaments.

Also in 1951 *Sistema Natural de la Musica* by Augusto Novaro appeared in Mexico in a private edition.

This text sums up a lifetime of extraordinary xenharmonic exploration.

Novaro discusses every equal division of the octave in detail up to 31. He gives diagrams of instruments built to realize music in each scale; he describes how to move *between* different tunings by exploiting the tones in common to different equal temperaments--as, for example, the 12/oct and 15/oct scales, which share the notes C, E and G# in common, or the 16/oct and 20/oct scales, which share the notes C, Eb, Gb and Bbb. **[Novaro, 1951]**

Novaro offers a new system of notation for dealing with any possible equal-tempered scale, and examines the relative merits of each temperament according to different members of the harmonic series best represented in each scale.

Prior tomes use a witch-hunt approach, in which one scale is judged good, and all other bad. Partch's text, although tremendously liberating, and containing a variety of disclaimers, retains an overall flavor of polemic and insult.

Novaro's book is free of these defects.

He was the first to take every equal-tempered scale on its own merits; he was the first to discuss practical methods of realizing actual, notatable music in *every* equal-tempered scale. Novaro remains the first theorist and instrument-builder to consider the entire treasure-trove of equal-tempered scales as an infinite realm of possible music, rather than as a narrow set of numerologically-privileged abstractions. **[Novaro, 1951]**

It's tragic to realize that, despite his accomplishments, by 1951 Novaro was already an obscure figure. Julian Carrillo's fame had far outstripped Novaro's. Few people would have appreciated Novaro's work even if they had been able to read the Spanish of the 1951 edition.

But by the early fifties, electronic instruments were beginning to make their mark. This era saw the beginnings, in fact, of completely electronic composition in alternative scales.

The German composer Karlheinz Stockhausen emerged as one of the dominant musical figures of the post-war period. And in 1954 his subtractive-synthesis electronic composition *Studie II* was the first to make use of the non-octave scale 25th root of 5--that is, the ratio 5:1 divided into 25 equal parts (10.767 tones/octave). **[Stockhausen, 1955; Grove's Dictionary, 'Stockhausen, Karlheinz, ' pg. 151]**

At the same time Pierre Boulez wrote in *Die Reihe* advocating the use of new scales and new electronic media--specifically, tape recorders, oscillators, filters and the like:

> "In considering his electronic means, the composer has first to free himself from the conception of absolute interval. This can certainly be done. The tempered system of twelve equal semi-tones seems to lose its necessity at the very moment at which it passes from chromatic organization to the Series. There have already been experiments with intervals of less than a semi-tone: of quarter-, third- and even sixth-tones. ...In fact, to select a fundamental unit other than the semi-tone, means to conceive a kind of temperament peculiar to a single composition; all intervals are to be heard as deriving from this fundamental tempering, thus affecting the listener's conditions of perception. ...This tempering may take place within the octave...or, it is equally possible to construct in such a way that the interval with which the *demarche* of the scale commences is other than the octave. ...In this way it would be possible to derive from one structure based on wide intervals, i.e., having a wide compass and a semi-tone as the unit, a corresponding structure based upon micro-intervals, in which the compass would be greatly reduced and where the unit would be either a very small interval or irregular intervals defined by a series." **[Boulez, 1955]**

Neither Stockhausen nor Boulez carried through on their intuitions, however. In part the problem devolved from the inaccuracy of analog electronics: vacuum-tube oscillators tended to heat up, drift, and detune. And in part the sheer arduous back-breaking SCUTWORK of tape composition was to blame: *thousands* of hand-spliced fragments of tape had to be painstakingly pieced together to generate a few *minutes* of music.

No wonder both Stockhausen and Boulez subsequently moved away from purely electronic and into acoustic serialist musical forms.

But on the horizon loomed the digital computer, offering a solution to all these problems.

In 1957 Max V. Mathews of Bell Laboratories wrote the first acoustic compiler for a mainframe binary computer. Called Music I, II, III, IV and eventually Music IVF (the F standing for Fortran, since Mathews grew tired to rewriting the entire program in assembler code every time Bell Labs upgraded to a new computer), Mathews' program permitted a composer to specify with incredible accuracy any desired frequency and overtone structure. **[Mathews, M. V. and Guttman, N., 1959; Roads, 1980]**

promised to revolutionize microtonality. For the first time *any* desired scale could be realized accurately. Compositions of unlimited complexity, with timbres composed of *any* kind of overtones (either harmonic or inharmonic) could be numerically calculated, written to computer tape in binary form, and played back as sound. **[Mathews, 1961]**

With the advent of Max Mathews' breakthrough program, the stage was set for an explosion of xenharmonic compositions.

THE GOLDEN AGE OF COMPUTER MUSIC: 1960-1980

In 1961 M. Joel Mandelbaum completed his monumental doctoral thesis at the University of Indiana. *Multiple Division of the Octave and the Tonal Resources of 19-Tone Temperament* had started as a simple discussion of the 19-tone equal-tempered scale but became much more comprehensive. **[Mandelbaum, 1961]**

Deeply influenced by Yasser's book, Mandelbaum determined to research the background of the 19-tone scale. The more thoroughly he studied his subject-matter, however, the more he was drawn toward an evenhanded consideration of *all* the equal temperaments. **[Mandelbaum, personal communication]**

As a result, Mandelbaum's thesis is the first extensive piece in English to consider in depth and on an equal footing a vast wealth of different scales, both just and equal-tempered. (Barbour's earlier book set up unusual equal temperaments mainly as straw men; each scale was knocked down for this or that presumed "defect.")

The importance of Mandelbaum's work cannot be overstated. He was the first to summarize in English the work of Ariel and Haba. Neither of these writers is yet available in English translation (except for one of Haba's works, translated by Darreg, and several early articles).

Mandelbaum was the second (after Barbour) to discuss the relative merits of systems from 12/oct through 118/oct, along with their historical precedents. And Mandelbaum remains the first to systematize according to Bosanquet's formulas most of the equal-tempered scales as positive or negative (that is, fifths that fall short of the 701.955-cent third harmonic or fifths that exceed the third harmonic).

His distinction between the two camps of xenharmonists also proved far-reaching: Mandelbaum was the first to discuss explicitly the schism between microtonalists who ranked members of the harmonic series along a spectrum of dissonance and consonance, and others who considered *all* members of the harmonic series equally important. The first group, Mandelbaum pointed out, tended to gravitate toward just intonation or 53- or 72-tone equal temperament; the second group were drawn toward equal-tempered scales outside the pale of traditional theory--13-, 15-, 18- and 23-tone equal temperament, for example.

Multiple Division of the Octave is also a work of immense scholarship: many obscure names were rescued from oblivion and put into historical context in its pages. Most of ***this*** history from 1870-1960, in fact, specifically cites Mandelbaum's thesis. The first half of this paper would be largely *blank* if Mandelbaum's work were not available as a detailed reference.

But his crowning contribution was a set of 9 piano preludes.

Mandelbaum was not content simply to theorize. He set out to compose in a completely non-12 scale (not a simpe subdivision of the semitone), using the same methods Yasser had used: by wheeling two pianos into proximity and tuning the seven white keys of one piano 1/19 octave flat, then tuning the seven white keys of the second piano 1/19 octave sharp. The two sets of five black keys of both pianos were both tuned to their closest equivalents in the 19-tone system. So doing, Mandelbaum was able to write vivid and effective music in 19 *without* building exotic new instruments or battling for time on a mainframe computer.

By any standard *Multiple Division of the Octave* stands as one of the major sources for microtonality in the twentieth century.

In the same year, James Tenney produced a set of increasingly-xenharmonic computer music studies at Bell Systems Laboratory in Murray Hill, New Jersey. Tenney's first effort, *Noise Study* (1961), broke with western tradition and also transcended the limitations of *musique concrete* by precisely specifying mean frequencies, noise power, frequency trajectories and rates and probabilities of change for each parameter. Subsequent computer music pieces did away with standard notions of pitch and timbre to explore the twilight region between noise and harmony, chaos and determinacy, and harmonic and inharmonic timbres. **[Tenney, 1963]**

Four years later, in 1966, John R. Pierce produced the first systematically non-12 piece of computer music. His *Eight-Tone Canon* was designed to test a theory about the consonance and dissonance of harmonic-series timbres in the 8-tone equal-tempered scale. Pierce judged that the rules for harmony would be particularly simple for harmonic timbres in the octophonic scale: *odd* scale-degree-dyads would sound dissonant when played together, while *even* scale-degree-

dyads would sound consonant. **[Pierce, 1984; Pierce & Mathews, 1969]**

His musical examples remain open to interpretation: dyads consisting of successive scale-degrees sound to my ears like complex and interesting consonances, while Pierce considers them dissonant.

But these considerations are trivial compared to the fact that Pierce used the computer to realize music in a completely new scale--one that had never even been discussed in the literature.

Jean-Claude Risset's groundbreaking investigations into the physical basis of trumpet timbre led the way into new universes of sound-colour. Risset quickly discovered that most of what had been written about musical timbre in acoustics and engineering texts was ***wrong***. *"I had to convince myself that the recipes of respected acoustics treatises [like H.F. Olson's] did not work. As one may judge from tones synthesized from recipes, they did not."* **[Risset, 1984]**

The steady-state timbre of a sound is relatively unimportant; instead, the first 100 milliseconds (1/10 second) of a musical sound is largely what determines our perception of timbre. **[Olson, 1957; Pierce, 1984; Risset, 1985]**

Most timbres are characterized not by a fixed set of partials but by the mathematical function according to which sets of partials grow or decay through time.

Detuning the partials creates a notable sense of liveliness and "warmth."

And in many sounds, the human ear hears a fundamental frequency that is not even present!

Risset's conclusions called into question the idea that harmonic-series timbres were needed to avoid beats. And the remarkable beauty of his computer music, which depended in large part on completely inharmonic timbres, threw into doubt most of the criteria by which equal- and non-equal-tempered scales had formerly been ranked as "good" or "bad."

If a computer allows us to generate partials with any desired amplitude and frequency, why should we care whether a particular division of the octave "lines up" with a given set of harmonics?

Beats can be eliminated completely; *we can simply tailor the timbre to the scale.*

John R. Pierce's 1966 letter "Attaining Consonance In Arbitrary Scales" (*Journal of the Acoustic Society of America*, 1966) and his chapter in the book "Music By Computer" **[von Foerster & Beauchamp, 1969]** made precisely this point.

Risset's 1969 composition *Mutations* is an extravaganza of inharmonic timbres and non-western tunings. Throughout most of the second half of the 11-minute composition Risset traverses various members of the harmonic series from 1-64; through much of the first half of the piece, he regales the listener with utterly inharmonic sounds not found anywhere in nature.

These lessons were not wasted on composers and theorists.

Throughout the late 1950s and early 1960s Ervin Wilson exhaustively examined the properties of nearly all the equal-tempered scales between 12 and 53 tones/oct. Heavily influenced by Yasser and Fokker, Wilson started with the 31-tone scale and built a breathtakingly-crafted 5-octave metallophone instrument, the Chromophone, to explore the tuning. He quickly branched out in the early 1960s to retuning guitars in many different systems; at first, 19-tone equal temperament, then 22-tone, then many other systems. Using guitars with artificially elongated necks and two guitars detuned by 1/41 of an octave, he was subsequently able to explore equal temperaments as high as 41.

During this period he assisted Harry Partch in the second edition of *Genesis of A Music* and drafted a number of the diagrams in Partch's book.

Wilson also built and tuned what he called "tubulongs"--tubular arrays that sounded much louder than wooden- or metal-bar instruments because the aluminum tubes formed their own resonators.

He laid his tubulongs out in a variety of different "keyboard" arrangements. Originally derived from Bosanquet's and Fokker's designs, Wilson's keyboard layouts vaulted far beyond the earlier generalized keyboard work to explore optimal 2-D arrangements of keys in a vast number of just intonation and equaltempered systems.

In 1986 he collaborated with the instrument-builder F. Scott Hackleman to construct a 19-tone clavichord with hexagonal keys. The generalized keyboard in the Wilson-Hackleman clavichord has become well-known and serves as a model of its kind. **[Wilson, personal communication; unpublished letters, 1962 ff.]**

At the same time Wilson was investigating just intonations, lifting Partch's work out of the tonality diamond and into Fokker's abstract ratio space.

By 1967 John H. Chalmers Jr. (then a graduate student at the University of California at San Diego) managed to wangle time on a mainframe. Come semester's end, any researchers who had computer time left over usually gave it away to the first comer. (Provided the lucky recipient was willing to stay up until 3:00 in the morning to make use of the machine!) This, because U.S. Government policy punished researchers who didn't use all their computer time each semester.

Armed with hours of mainframe computer time Chalmers wrote a series of Fortran programs to calculate guitar frettings, the cents error by which each member of the harmonic series from 1 through 37 fell flat or sharp of the scale-steps,

and the cents, string-lengths, decimal fraction and harmonic series approximation of the scale-steps in all equal temperaments between 1 and 1200 tones per octave. **[Chalmers, personal communciation.]** Hall incorrectly states that Stoney "seems to have been the first to carry out an extensive computer-aided evaluation of harmonic-interval approximations in equal temperaments." **[Hall, 1985]** In fact Chalmers duplicated this work in 1967, three years earlier than Stoney. Chalmers also covered equal temperaments 1-1200 while Stoney only went as far as 72. **[Stoney, 1970; Chalmers, personal communication; Chalmers, Xenharmonikon 1]**

Because he was in close contact with Erv Wilson, Chalmers also wrote a number of programs to explore abstract sets of just intonation pitches.

In 1967, examining the voluminous printouts of Chalmers' ratio-sets, Wilson hit on the idea of combinatoric scales.

As Kraig Grady has said, "just intonation took a giant leap forward" when Wilson discovered the ratio-space structures he calls hexanies, dekanies, eikosanies, and cross-sets. **[Grady, 1986]**

Previous just intonation composers--including Harry Partch--had been faced with the prospect of either limiting themselves to a single key or navigating "an infinite sea of commas." **[Wilson, personal communication]**

For the first time Wilson's tonic-less harmonic structures offered a way out.

He limited the number of steps in a just scale by building his harmonic/melodic structures out of combinatoric sets. (Combinatorics is the mathematical discipline which details the number of different ways in which a group of things can be ordered.) By taking all possible products of 2 out of a set of 4 numbers, or 4 out of a set of 8 numbers, etc., Wilson was able to generate a set of non-centric harmonic/melodic structures which were both logically coherent and musically beautiful. **[Wilson, personal communication]**

Wilson's structures represent a break with the Partch tradition, however, insofar as they dispense with 1/1. Though they must be referenced to a fixed frequency in order to be realized on an instrument, Wilson's original harmonic/melodic structures do not require and do not involve a 1/1--an idea alien to some just intonation advocates.

In addition to combinatoric structures Wilson has made subtle use of tetrachordal interval permutation to derive a number of the *thats* of North Indian ragas by operating on various sets of tetrachords. **[Wilson, 1986]** He also introduced the unit-proportion method of harmonizing tetrachords, and extended Kathleen Schlesinger's *harmoniai*. He also developed a set of a scales which he calls the *diaphonic cycles*, "which combine the repeated modular structure of tetrachordal scales with the linear division of Sclesinger's *harmoniai*." **[Wilson, personal communication; Chalmers, 1993; Schlesinger, 1939]**

Along with Harry Partch and Augusto Novaro, Erv Wilson qualifies as one of the most important microtonal theorists of the twentieth century.

Why isn't he better-known?

In part because of the apothegmatic density of his writings. Reading a Wilson article is like being hauled up from the bottom of the Cayman Trench in a bathyscaphe--*rapidly*. The effort to decompress Wilson's gnostic piths and gists provokes acute vertigo.

His few writings are so cryptic, with so many intermediate steps excised, that it becomes almost impossible to trace his train of thought.

The other reason for Erv's relative obscurity is that he has had vast influence as a teacher, but relatively little as a composer and performer. "I'm a theorist," he is fond of saying, "not a composer," and discounts his considerable skills as a percussionist and keyboardist.

And, as with Carrillo vs. Novaro during the 30s and 40s, the gifted musical performer hogs the limelight, while the more influential theorist is often ignored until decades later.

The true extent of Wilson's theoretical explorations remains unknown. Reluctant to publish, and then only in cryptic fragments, Wilson may well have progressed far beyond the few writings he has released in various publications.

Meanwhile the rest of us can only wait and see.

During the same period--the late fifties and early 60s--one of the most important xenharmonic figures emerged: Ivor Darreg.

Darreg's first flirtation with non-12-tone systems came in the 1920s, when he produced quartertones on his cello as a teenager. But his first extended foray into systems which **weren't** subdivisions of 12 occurred in the 1950s as a result of a patent search on non-12 keyboards. In the literature he encountered a keyboard patent by Erv Wilson. He subsequently met and corresponded with Wilson and Chalmers, sharing ideas and picking up the notion of the tubulong and the refretted guitar.

Like Wilson, Darreg was an avid instrument-builder. But UNlike Wilson, Darreg was a copious and vastly gifted writer and a prolific composer. He was also ready, willing and able to put his ideas down in published articles, magnetic tapes,

and eventually MIDI data streams.

Darreg's influence remains pervasive. Many guitarists have "de-twelvulated" their instruments (in Darreg's terminology) because of his landmark article on non-12 guitars in *Guitar Player.* His worldwide correspondence and tape exchange network has let listeners on four continents hear compositions in many different scales for the first time.

He has scored a number of firsts: Darreg was the first composer to recognize explicitly the different characteristic "sound" of each equal temperament. In his series of *Xenharmonic Bulletins*, starting with the *Special Bulletin* of 1963 (which many would consider *Xenharmonic Bulletin Number Zero*) Darreg brought together a vast array of citations, historical sources, theoretical calculations and his own years of experience in composing in and building instruments for all the equal temperaments. **[Darreg, 1963, 1966, 1967, ff.]**

Like most composers of the early 20th century, Darreg started with the 24-tone or quartertone scale. But **unlike** most other theorists, Darreg leaped ***beyond*** simple divisions of the 12-tone scale and began to refret guitars in a wide variety of different, totally non-12 scales. **[Darreg, 1947; Darreg, 1975 ff.]**

He eventually refretted guitars in no less than 7 different scales: 14/oct, 15/oct, 17/oct, 19/oct, 22/oct, 24/oct and two 31/oct guitars--one with nylon strings, another electric guitar with metal strings.

In 1961 Darreg heard a tape of Mandelbaum's *9 Preludes for 19-Tone Piano* and retuned a home-built electronic organ to 19. He discovered that what he had thought was the "sound" or "mood" of Mandelbaum's music was in fact a characteristic of the 19-tone scale.

Retuning his organ to many other equal-tempered scales, Darreg quickly discovered that each scale had its own "mood" or "sound."

In *Xenharmonic Bulletin Number 5*, from 1975, he explicitly codified this knowledge for the first time. In *Xenharmonic Bulletin Number 7* he set out extensive fret-tables, allowing anyone to retune their guitars to a large number of different scales. In *Xenharmonic Bulletin Number 10* he discussed the relative advantages and disadvantages of every equal temperament from 5/oct through 144/oct (!) without singling out any given scale for condemnation, and without turning the scale-hunt into a witch-hunt with "sentences first, verdicts later" (in the words of Lewis Carroll's Red Queen).

Darreg was able to arrive at this overview in large part due to his extensive experience in composing in many, many different equal temperaments.

In the process he discovered that scales condemned out of hand by earlier theorists could *easily* be made to sound beautiful and bewitching. In building a 13-tone bar instrument, for example, Darreg deliberately used wedge-shaped bronze slats to "tame" 13 with a unique mellow timbre.

The resulting music shattered the general wisdom of the textbooks.

By making breathtaking music in scales previously considered anathema (13/oct, 14/oct, 15/oct, 17/oct, 25/oct, and many others), Darreg proved convincingly that ALL equal temperaments were worthy of exploration.

He went on to propose (along with the present author) that all scales could be arranged on a spectrum: from "most biased toward melody" to "least biased toward melody." (Or, conversely, from "least biased toward harmony" to "most biased toward harmony.") **[Darreg & McLaren, 1991]**

This led to an important conclusion: ***all*** equal temperaments are ***equally useful*** for composing beautiful music--but ***different*** temperaments require ***different kinds of music***. **[Darreg and McLaren, 1991]**

Scales without fifths--viz., 9, 11 or 13 tones per octave--favor a fast-paced contrapuntal style with brisk percussive timbres, while scales with excellent fifths, like 31, 41, 53 or 118 tones per octave, favor a triadic homophonic style of composition.

Darreg's megalyra family of instruments, his unique "elastic tuning" organ--whose chords actually retuned themselves toward just intonation even when tuned in completely non-12 systems--and his magnetically-amplified clavichord, all deserve mention.

The good humor, wit and sheer readability of his music writing deserves special citation. No other author in the field of microtonality has produced a body of essays and monographs so enjoyable and well-written.

Composer, lecturer, author of more than 500 pages of expository text, Darreg has for 40 years been "a fountain of information about non-12 scales." **[Reinhard, *Pitch*, Volume 4, 1991]**

Back on the digital frontier, composers continued to explore non-12 scales.

In 1966, Gerald Strang's *Computer Piece Number 2* exploited the previously-unheard 21-tone equal temperament. And in 1969 Arthur Roberts of the Argonne National Laboratory produced *Sonatina for CDC-3600*, the second movement of which constituted "an exercise in quarter- and eighth-tones." **[von Foerster and Beauchamp, 1969]**

During the late 60s the composer Ernst Krenek produced an electronic score in the 13-tone equal-tempered system.

Used as a background for an experimental film, the score gained rapidly gained notoriety for its non-Western tonal complexes **[Wilson, personal communication]**.

In the late 60s and through the 70s David Rothenberg published a provocative series of articles analyzing the deep structure of xenharmonic scales. Rothenberg expanded Yasser's earlier ideas of abstract diatonicity: "These concepts relate the tervallic structure of scales to the perceptibility of various musical relations in music using these scales. Only the relative sizes of the intervals between scales tones, not the precise sizes of these intervals are pertinent." **[Rothenberg, personal communication]**

His essential idea was to create a *difference matrix* from the successive intervals of an n-tone scale--in effect, to take the numerical derivative of the scale in two dimensions. He then calculated a number of properties from the matrix, the most basic of which being*propriety*--a measure of how ambiguous the scale's intervals will appear to the listener. Rothenberg called scales with overlapping interval classes *improper*: these intervals can create aural illusions in a naive listener, akin to the well-known diagram of a box which alternatively appears above the printed page or below it, depending on the observer's state of mind. This insight serves to explain, for example, some of the properties of the 22-tone scale, in which ascending figures must be notated as thought they were descending and vice versa.

Rothenberg's quantification of the idea that all scales exhibit a pattern of large and small intervals which allows even a naive listener to classify them by ear has exerted lasting influence on other composers and theorists. It is a significant extension of Yasser's idea of abstract diatonicism and probably influenced both Bolzano and Easley Blackwood. **[Rothenberg, 1969, 1975, 1978; Blackwood, 1985; Bolzano, 1980; Chalmers, 1993]**

In 1970 Ezra Sims and Franz Richter Herf independently began to compose spectacular, affecting music in the 72-tone scale. Herf quickly gathered a group of skilled microtonal instrumentalists in Salzburg, eventually producing a series of volumes entitled *Mikrotoene I, II*, &c., to record the proceedings of a set of yearly microtonal conferences at the Mozart Institute in Salzburg. **[Sims, personal communication]**

Sims, meanwhile, produced a steady stream of carefully-crafted, moving music far outside the mainstream. He continued to gather acclaim and impressive notices, leading up to his 1991 interview and article in *Perspectives Of New Music.* **[Sims, 1992]**

Also in 1970 Stoney published the results of a computer evaluation of harmonic-series approximations in equal temperaments. He discussed equal temreaments up to 72/oct, and used combinations of all harmonics from 8 through 15. His results favored 72, 22, 24, 31 and 53-tone equal temperaments.

Meanwhile, in the late 1970s the composer and engineer George Secor convinced Motorola to build the Scalatron.

This electronic organ, with circuitry designed by Richard Harasek, was capable of being tuned to any just or equal temperament with an accuracy of 1024 parts per octave. It came with a system which made use of a cathode ray tube and electronic counter circuits to make the most of the (at the time) unprecedented tuning accuracy.

Three Scalatrons were also built with generalized keyboards. One was purchased by Queens College in New York (where Joel Mandelbaum presided over it), one was bought by George Secor, and the other was shipped to McMaster University in Ontario, Canada where the composer Paul Rapoport makes extensive use of it.

The McMaster model used 56 keys per octave, making the McMaster Secor generalized-keyboard Scalatron the most useful and universal xenharmonic keyboard instrument to date.

Its inventor, George Secor, has recorded a large number of improvisations in previously-unheard equal temperaments: 11/oct, 10/oct, 20/oct, 27/oct, and many others.

Between 1972 and 1981 John Chalmers' journal *Xenharmonikon* exposed readers to a wide variety of different tunings, notations and composers. Chalmers' role in exploring equal and just temperament has been touched on, but his influence extends far beyond the immediate circle of Darreg, Wilson and those in the Los Angeles/San Francisco area. Chalmers has been instrumental (all puns intended) in bringing together xenharmonic composers in Europe, Canada, Mexico and the U.S.

His own contributions, ranging from his monumental 1993 book *Divisions of the Tetrachord* to his tritriadic method of deriving just scales, to his open-minded discussions of equal-tempered scales, to his 1981 joint paper (with Erv Wilson) delivered at the fourth International Computer Computer Music Conference, have exerted a deep and lasting influence on the field.

Chalmers' publication has garnered praise in *The Computer Music Journal*. And, even though it reached the apex of its influence in the late 1970s, it continues to shape the course of xenharmonic composition and theory into the 1990s.

As the sixties drew to a close, Robert Moog's invention of the synthesizer opened new doors for non-12 composers. For the first time it became possible (as Wendy Carlos demonstrated in 1969) for a single composer to use a single electronic

instrument and a multi-track tape machine to generate an entire orchestral composition. And with the advent of the voltage-controlled synthesizer, any desired equal temperament could be had with the turn of a knob--by varying the number of volts/octave, one obtained any equal temperament within the range of stability of the synthesizer's oscillators.

Throughout the fifties and early sixties Lou Harrison also produced just intonation music with large--and often conventionally-trained--ensembles. His *Pacifika Rondo* (1964) employs a number of home-built psalteries and ethnic instruments; as early as 1939 Harrison had composed a concerto for violin and percussion instruments (including brake drums) and he had extensively explored non-Western percussion ensembles, most notably in *Double Music* with John Cage. By the sixties Harrison's music had become widely available on LP, extending his considerable influence.

In 1968 Walter O'Connell submitted the paper *Tone Spaces III* to the magazine *Die Reihe.* In his monograph, O'Connell explored equal subdivisions of the ratio phi (1.618304), closely approximating the 36-tone and 19-tone equal temperaments. But O'Connell's most important contribution lay in his proposal that the partials of the timbres used should also conform to the ratio of the golden section.

This is one of the first suggestions that actually puts into practice John Pierce's groundbreaking idea of "Attaining Consonance in Arbitrary Scales."

In 1979 Dirk De Klerk duplicated part of Stoney's work, but using an absolute cents-error criterion, rather than measuring deviations from harmonic series members in fractiosn of an octave. De Klerk carried out his evlauation of equal temperament harmonic series approximations to 120-tone and favored 34 and 46 over 53, 19, 31 and 41. As usual, the point of these evaluations seems to have a musical witch hunt--some scales are found to be "good" and others "bad." No one (other than Darreg) seems to have realized that each scale is musically useful and boasts a unique "sound."

In the 1970s a large number of instrument-builders followed Harry Partch's and Erv Wilson's lead. Kraig Grady, Glen Prior, Jonathan Glasier, Ben Johnston, Cris Forster, Lou Harrison, David Doty, Bill Alves, Craig Anderton, Henry Rosenthal, Warren Burt, Denny Genovese, Buzz Kimball, John Negri. Others, including Johnny Reinhard, David Rothenberg, Arturo Salinas, Loren Rush, Harold Seletsky, Dr. Robert Shaughnessy, Martin Vogel and Daniel Wolf all wrote for conventional ensembles and/or used computers to modify conventional soundfiles, and composed in various just intonation systems throughout the 70s.

Some were primarily electronic composers: Anderton, Rush, Salinas, Polanksy, Alves, Pressing, Burt. Others favored acoustic (primarily home-carpentered) instruments: Grady, Harrison, Rosenthal, Genovese, Wolf, Rothenberg. Some leaned toward improvisation: Glasier, Grady and Seletsky.

Others extended Partch's and Wilson's systems in various ways: Ben Johnston, long-time Partch assistant and student, wrote a notable set of quartets (6 so far) in which the pitches swing freely from one just tonic to another, mapping a kaleidoscopic universe of different just arrays. The opening of his 1964 *Quartet Number 2*, for example, uses a 53-tone just intonation scale, while the middle section treats serially a 31-note scale. **[Yates, 1969]**

Cris Forster's remarkable set of instruments enhanced Partch's 11-limit system by adding ratios of 13. He also explored new realms of sound: Forster coined the phrase "ambisonance" to describe the effect of intervals neither traditionally consonant nor traditionally dissonant. Featured in pictorials in *Connoisseur* and *OMNI* magazines, his superbly-crafted instruments include the Chrysalis, Harmonic Canon IV, and other offshoots of the Partch phyla. **[Forster, 1985]**

Some composers preferred to borrow from or extend the traditions of other cultures; Jody Diamond's American Gamelan Institute is a center for cross-pollination between western and Javanese/Balinese gamelan traditions.

Other composers continued the tradition of subdividing the steps of the 12-tone scale. Tui St. George Tucker's *First Quartet* and *Second Quartet* make extensive use of quartertones, as does her choral work "Indian Summer."And in the late 1960s John Eaton produced his "Quartertone Fantasy" for two pianos. Through out the 70s and 80s he continued to work in subdivisions of the 12-tone scale, producing a variety of operas and chamber music compositions.

In 1967-69 John Cage and Lejaren Hiller's algorithmic composition HPSCHD used passages in every equal temperament between 5 and 56 tones per octave. **[Yates, 1969]** Hiller had previously composed quartertone works; in addition to a good deal of 12/oct music, he subsequently produced a 31-tone algorithmic piece using MIDI and the Oberheim Matrix 12 synthesizer.

In 1975 the film composer Emil Richards became the first to score a film in the 31-tone equal system: *Klute*. **[Wilson, personal communication]** In the same year Hubert S. Howe's computer piece *Variations On The Overtone Series* set up an array of harmonically- and inharmonically-related pitches impossible to realize outside of the computer medium. Howe subsequently became interested interested in the 19-tone scale, giving a talk on the subject at the 1993 International Computer Music Conference in Tokyo in 1993. **[Howe, 1975, 1993]**

By the late 1970s computer musicians had also taken up non-12 scales *en masse*. The most important computer musicians included John Chowning, Loren Rush and Bill Schottstaedt at CCRMA, Jon Appleton at Dartmouth, Larry Polanksy at Mills and, in the early 80s, Dartmouth, Dexter Morrill at Colgate College in New York, and the group of composers who formed the landmark League of Automated Composers in San Francisco all roamed freely outside the 12-tone scale.

Bill Schottstaedt chose to combine the previously-condemned 11/oct scale with 48-tone to great effect. And in his well-known interview in *Perspectives Of New Music* he militantly states "I like beats," and gives as examples some of the remarkably beautiful music he composed for the Samson Box--all in scales previously considered anathema, unusable, and unworkable.

The League of Automatic Composers, meanwhile, resurrected Max Meyer's 7-limit 29-tone just intonation scale in an algorithmic guise. (1978-1982: David Behrman, John Bischoff, Donald Day, Rich Gold, Jim Horton, Tim Perkis.) Their later incarnation, The Hub, has explored algorithmic uses of the 31-tone scale. (1986-present: John Bischoff, Chris Brown, Scot Gresham-Lancaster, Tim Perkis, Phil Stone, Mark Trayle.) **[Bischoff, Gold, Horton, 1978; Bischoff, 1991]**

In 1975 James Dashow's "Whispers In the Darkness" won the Bourges Prize, incidentally using completely non-12-tone spectra as "chords." His 1977 "Effetti Collaterali" extended the process, putting into practice Pierce's suggestions for attaining consonance is completely arbitrary scales.

In 1978 the Australian composer Warren Burt completed *Studies For Synthesizer*. He used a Serge modular analog synthesizer controlled by digital counter circuits; the resulting 3-, 5-, 6- and 7-voice canons explored many just and equal-tempered tunings, including Harry Partch's 43-tone just array, the 5, 7-, 19-, 31- and 50-tone equal tempered scales, and even 300-tone equal temperament.

Sometime during the late 1970s the computer composer Wayne Bateman "wrote and recorded a composition based on a 13-tone row," the second known instance of serial technique applied completely outside the 12/oct scale. (Boulez employed 24-tone serial structures in 1946 and Stockhausen in 1954 applied serial technique to the 25th root of 5.)**[Bateman, 1980; Grove's entries for Boulez and Stockhausen]**

By 1979 Dexter Morrill had broken free of 12 and headed into new territory in his composition for computer and soprano, "Six Dark Questions." **[Morrill, personal communication, 1992]** Also in 1979 Schottstaedt's composition "Daily Life Among the Phrygians" explored non-12 scales--a consistent interest of this remarkably gifted composer.

By the start of the 80s electronic and computer music was rife with microtonality. MIDI was just around the corner. The move outside 12 was ready to shift into high gear.

MICROTONALITY MOVES INTO THE MAINSTREAM: 1980-2000

The first microtonal compositions of the 80s were Easley Blackwood's profoundly influential *12 Microtonal Etudes for Electronic Music Media*. **[Blackwood, 1980.]**

For the first time a score appeared with a unified set of notations for all equal temperaments between 12 and 24 tones per octave; and the record accompanying the score was a breakthrough. Listeners could follow a complete set of non-12 scores while they heard (probably for the first time) tunings so far outside the 12-tone system that few previous theorists had even considered them: tunings as wildly heterodox as 13/oct, 16/oct, 20/oct and 23/oct.

Not only that: Blackwood's 13-tone, 14-tone, 15-tone, 17-tone, 21-tone and 23-tone Etudes are beautiful music. Here, for the first time, was proof in the form of an LP and a printed score...an unanswerable demonstration of the viability of of composition in scales the likes of 13 and 23.

In explaining his interest in composing outside of 12, Blackwood wrote:

"...I have long suspected that theorists are off the mark in their rejection out of hand of any tuning that does not produce consonant triads... ...these Etudes prove that equal tunings can produce expressively compelling progressions of hitherto alien harmonies and melodies." **[Blackwood, 1980]**

In 1981 John Chowning's computer composition *Stria* divided phi (1.618304)into 9 equal parts to obtain a nearly exact 13-tone scale. The resulting music, haunting and possessed of a vast cold beauty, impressed many listeners.

From the early 80s through the end of the decade, Bill Schottstaedt continued to produce a set of militantly microtonal studies for Stanford's Samson Box synthesis array: *Water Music I* and *II, Colony I-V, Dinosaur Music, The Gong-Tormented Sea* and many other compositions, all well outside the 12-tone system.

He discovered that his ears rapidly became acclimated to non-12 scales. "What sounds in tune is very dependent on context. An interval or chord that initially sounds out of tune may come to sound in tune in the course of piece. It's a matter

of setting up expectations. One obvious example is the first movement of *Water Music*, where the eleven-tone intervals sound right by the end of the piece." **[Schottstaedt, "Six Composers On Non-Standard Tunings, Perspectives of New Music," 1992, No. 1, p. 200.]**

In the late 70s and early 80s the just intonation computer music composer, programmer and hardware designer Ralph David Hill had built entirely from scratch the 4-voice synthesizer "The Quadvox." He used it to realize advanced higher-limit just intonation music, including a just version of Ivor Darreg's *Study in Fifths*. In the middle 80s Hill moved to the University of Florida and built another, far more advanced, computer music system entirely from raw parts: the Platypus. This system was capable of analysing and resynthesizing sounds using Fourier Analysis in conjunction with Macintosh computer programs written by Hill. Most recently he has used the system to realize 11-limit just intonation vocal works.

Also in the late 70s the Canadian theorists Maurice Yunik and G. W. Swift wrote computer programs to examine the relative value of various equal-tempered scales and in 1980 published a *Computer Music Journal* article replete with charts comparing the equal temperaments from 0 to 60 tones per octave. **[Yunik and Swift, 1980]** This pioneering investigation anticipated both Don Hall's and Wendy Carlos' subsequent examinations of the relative merits of equal-tempered scales. Yunik and Swift also devised new 19-tone keyboards, aided by undergraduate students M. G. Gossen, who learned and performed one of Joel Mandelbaum's 19-Tone *Preludes* and performed it at a seminar at the University of Manitoba, and D. Loeppky and D. Fallowfield, who helped with the electronic side of the 19-tone organ and innovative keyboard interface. **[Loeppky and Fallowfield, 1979]**

In 1985 Loren Rush produced *Travelling Music* for the Samson Box and a just-intonation piano. In the same year Donald E. Hall published an article in *Interface* magazine analyzing all the equal temperaments between 1 and 612 tones per octave. **[Hall, 1985]**

In the late 70s and early 80s John Glasier Sr. toured college music classes throughout the San Diego area, playing xenharmonic music on his viola. (It may interest the reader to learn that the author owes his own interest in microtonality to a 24/oct improvisation by John Glasier Sr. in 1978 in a freshman introductory music class.) John Glaiser and Jonathan Glasier produced many tapes of duo improvisations in non-12 tunings, and John Glasier Sr. composed a number of striking pieces in 31 (among other scales).

Roberto Rue of Argentina published an article in the 1985 issue of *Interface* discussing equal temperament approaches to approximating an harmonic series scale.

Easley Blackwood's landmark book *The Structure Of Recognizable Diatonic Tunings* dates from the same year. In it, he elaborates on Yasser's notion of an abstract "diatonicism" underlying the actual pitches of a scale and extends it to define and classify a variety of completely non-12 systems. Blackwood breaks with conventional theory and states ont he basis of his extensive compositional experience that scales considered by earlier theorists to be "useless" are actually perfectly suitable for producing beautiful music. As examples, he gives the 15-tone scale, the 13- and 23-tone scales, and the 14-tone scale. His later article in the 2nd microtonal issue of *Perspectives Of New Music* (1992) examines the usable modes and harmonic progressions available in 15, 16, 17 and 19-tone equal temperament. **[Blackwood, 1985, 1992]**

Rudolf Rasch also published a slew of articles in *Interface* (and elsewhere). Among his many concerns, he addressed the question of notations suitable for all the equal temperaments, the best systems for approximation various members of the harmonic series, and keyboard layouts and compositional practice in various equal-tempered and just systems.

Rasch exerted profound influence throughout the 1980s as editor of the Fokker-Huygens "Corpus Microtonale" series of scores and the "Library of Tuning and Temperament" series of books, including translations of volumes never before available in english.

Also in the 80s the Canadian composer James Tenney produced a piece for an harmonic-series piano, extending Conlon Nancarrow's work.

In 1986 Wendy Carlos'CD *Beauty In the Beast* treated listeners to a xenharmonic tour de force: she explored Tibetan r-gynd-stad scales, two completely original non-octave scales (Carlos Alpha and Carlos Beta), a harmonic-series scale, a just intonation scale in which she modulated through 12 different just arrays (!), even an East Indian scale.

Jules Siegel's cassette "The Re-Awakening of Harmony" from the same year explores a wide variety of just intonations.

Terry Riley's *The Harp of New Albion* followed up the lead of La Monte Young's 70s "well-temperament" classic, The Well-Tuned Piano.

By the 1980s Dean Drummond's just intonation ensemble NewBand had staged performances of Partch classics along with many new compositions commissioned for his 31-note just array tubulong, the zoomoozaphone.

In 1983 the French xenharmonist Jean Etienne Marie published *L'Homme Musicale*, a musical textbook containing an extensive overview of 20th century microtonality.

Other French microtonalists of the 70s and 80s included Claude Ballif, who worked in quartertones; Jacques Dudon, whose article *La Gamme Doree* derived 19- and 31-tone equal temperament from the golden section, in a manner similar to Thorwald Kornerup's work of the 30s (Dudon also produced innovative musical instruments, many of them based on rotating glass plates with elaborately-inked patterns facing photosensitive CdSe cells--a process similar to the electronic-music experiments of the early 1920s in Britain, America and Russia); and Francois Baschet, whose steel sound-sculptures explored new realms of timbre and tonality.

Starting in 1985 the proceedings of the 1st and then the 2nd International symposia on microtonal music were published by Edition Helbling. The first symposium, held from May 10 to 12, 1985, featured a wide variety of speakers.

Ulf-Diether Soyka ov Vienna, Austria spoke on the subject "Ekmelik music--digital or analog?" His talk touched on the tendency of the ear to hear "ekmelik" or 72-tone equally tempered music as continuous divisions of the octave rather than discrete scale-steps.

Professor Alois Heine of Salzburg spoke about "Acoustic phenomena," and Dr. Kurt A. Hueber of Vienna discussed "Pseduo-harmonic partial overtones and ekmelik interval structure; a new sound-space for music theory." Prof. Horst-Peter Hesse of Goettingen and Salzburg spoke on "The fusion of musical timbres on the basis of a two-factor theory of consonance," while Prof. Rainer Zillhardt of Essen gave a talk entitled "Concerning Problems in the history of ordered structural analysis of tones," and Dr. Rudolf Rasch of Utrecht, Belgium discussed "The division of the octave and nonharmonic tone systems," in which he distinguished between divisions of the octave with functional fifths and those without traditional fifths (13, 16, 18 and 23/oct).

31-tone violinists Bouw Lemkes and Jeanne Vos of Utrecht spoke on "Microtonal Music in the Netherlands," and Prof. Kalus Ager of Salzburg discussed "The Ultrachromaticism of Ivan Vyshnegradksy as an insight into melody and rhythm," while Prof. Martin Vogel of Bonn spoke about "Microtonen in Rahmen der reinen Stimmung."

Prof. Rudolf Haase of Vienna gave a talk entitled "Auditory disposition and ekmelik intervals," while Prof. Jobst P. Fricke of Cologne discussed "Microtonal sound-structures--indentification and systematization" and Prof. Rolf Maedel of Salzburg spoke on the subject of "Microtonal harmonic functions."

During the 2nd microtonal symposium 2 years later, held from May 22-24 in Salzburg, Barbara Barthelmes of Berlin spoke on "Composition for Quarter-tones: Aesthetic positions," while Prof. Boguslaw Schaeffer of Salzburg discussed "New topics in microtonal music" and Dr. Rudolf Rasch of Utretcht talked about "A new normative notation for microtonal music: the fundamental notation." Gerhard Klosch of Vienna spoke "Concerning Euler's theory of consonance in relation to the ranking of tone systems in the infinity of tonal resources." Prof. Martin Vogel of Bonn spoke on "The contrast between emmelik and ekmelik musics," while Martin Draaf of Cologne spoke on "The Enharmonic Guitar," a just intonation guitar using ratios of 11, 13 and 17. Clemens Misch and Prof. Rudolf Wille of Darmstadt spoke on "Voicing logic from MUTABOR: a computer program," while Dr. Guerino Mazzola of Zurich discussed "Consonance, dissonance and tone symmetries," while Prof. Rolf Maedel of Salzburg discussed his paper "Transformations," based on divisions of Golden Section.

Dr. Kurt Anton Huebner of Vienna spoke on "Mathematical and physical basis for ekmelik intervals," while Prof. Rainer Zillhardt of Essen gave a talk dealing with "Chroma in "Beziehungsqualitat" and in "Fundamentaleigenschaft;" questions of precision in both papers." Prof. Horst-Peter Hesse of Salzburg discussed "Sound-distance measurement in musical intervals--an overview of mathematical definitions of interval," while Prof. Dr. Walter Gleseler of Cologne talked about "Critical remarks on composition with small intervals" and Prof. Franz Richter Herf of Salzburg spoke about "The intonation of ekmelik sound structures." (*'Ekmelik'* in all cases being the German language equivalent for *'xenharmonic'* or *'microtonal.'* In particular Herf used the word *'ekmelik'* to describe 72-tone equal temperament.)

Ever at the forefront of electronic and avant-garde music, Canada has proved particularly fertile ground for microtonality in the 70s and 80s.

The composer Bruce Mather oversaw McGill University's superb collection of Vyshnegradky recordings. As a member of the Vyshnegradksy Society and a recognized scholar of the composer's work, Mather was well qualified to present the master's compositions in new recordings.

His own work in the 36- and 48-tone scale includes the astonishing *Poeme du Delir.*

Quebecois composer Serge Provost's *Les Jardin Suspendus,* in various non-12 systems, provoked a recent "success de scandale" and is currently available on CD from The Canadian Music Council.

John Winiarz has also explored a number of different non-12 scales.

Paul Rapoport's *Songs of Fruits and Vegetables*, in 31-tone equal temperament, extended Easley Blackwood's pioneering work. His *Study In Fives*, in the rare and beautiful 25-tone scale, made a worthy contribution to the microtonal

literature. By the early 90s Rapoport was hard at work on a 15-tone guitar piece and a study based on Erv Wilson's just intonation combination product sets. He also contributed articles on notation and theory to *1/1, Interface*, and elsewhere.

In Australia a whole slew of composers escaped the 12-tone scale and produced subversive amounts of xenharmonic music.

Warren Burt's set of 19-note just intonation tuning forks generate eerily lovely harmonies in "Three Inverse Genera;" Ros Bandt's Arabic meantone-scale psalteries and a combination of live electronics and tape recordings produce completely non-western (and achingly lovely) music in "Genesis." Sarah Hopkins' "Songs of the Wind" and her cassettes Heart Music and Sky Music use (among other instruments) an 11-foot-long green plastic hose whirled overhead to generate members of the harmonic series.

Burt's influential 1978 work *Studies For Synthesizers* explored a cornucopia of just and equal-tempered scales previously unheard, including 300 tone (!) equal temperament, while his other 1978 work *Le Grand Ni Symphony* used digital counter circuits to set off 7-limit just intonation pitches in a tapestry of overlapping rhythms. His latest work, for MIDI synthesizers, includes the 19-tone *Mr. Yasser's Piano* (available on MusicWorks cassette 43) and his 1993 algorithmic epic of ravishing beauty, *Some Kind of Seasoning*, on a quartet of 90-minute cassettes.

William Coates' 31-tone ensemble of acoustic musicians regularly performs and records works completely outside the 12-tone scale. Coates contributed an article on 31 to Glasier's *Interval* magazine, and he has maintained a consistent interest in the 31-tone scale. **[Coates, 1984]**

Also during the 80s the Australian group *Gonghouse* (Neil McLachlan, Nerida Minty, Sarah Halls and Richard Barber) built their own set of just intonation instruments, composing and performing with them with a variety of settings. **[Burt, personal communciation]**

New Zealand composers Ross Harris and Phil Dadson also ventured outside the 12-tone scale, the latter visiting and videotaping Ivor Darreg in 1991 on a Fulbright grant. Dadson's group From Scratch recently produced a notable non-12 acoustic compilation, *Songs For Heroes*, a rich amalgam of Pacific sound-textures, non-western rhythms, and performance theater. **[Dadson, 1993]**

By 1991 even mainstream journals were discussing the microtonal tunings used by earlier composers. **[Barbieri, 1991; Haynes, 1991]** One writer even suggested that Beethoven originally composed his works in the 19-tone system! **[Gagliardo, 1989]**

British microtonalists of the 70s and 80s include Andy Spiceley, organizer of the 1989 SPNM Conference On Microtonality, Jonathan Harvey, composer of the marvellous xenharmonic computer pieces *Mortuos Plango Vivos Voco, Ritual Melodies* and the acoustic quartertone *String Quartet Number Two*, and Hugh Davies, a long-time electroacoustic composer whose works have appeared at American Festival of Microtonal Music concerts in New York and whose historical catalog of electroacoustic works is justly famous.

Also in the late 70s and early 80s, Johnny Reinhard's series of microtonal concerts became a staple of the New York concert scene. By the middle 80s his American Festival of Microtonal Music had built up a 3,000-name mailing list and a steady stream of critical praise from reviewers in *The Village Voice* and *The New York Times*. From 1986 through 1988 he produced a set of 4 limited-edition issues of the sourcebook *Pitch: For the International Microtonalist*.

In 1978 the percussionist Glen Prior put out the double LP *Moustache Blue* with Ivor Darreg. Together, they showcased a wide variety of just and non-12 equal temperaments. His composition *The Leaf* was susbsequently engraved by Rudolf Rasch's Corpus Microtonale Editions, the first printed composition to use one of Erv Wilson's hexanies.

During the early 1970s Jonathan Glasier served as Harry Partch's assistant during Partch's brief (and tumultuous) stay at UCSD. From 1978 to 1984 Glasier's influential journal Interval published a wealth of information about building and tuning non-12 instruments, and explored a vast range of equal-tempered and just intonation scales. Authors as diverse as George Secor (inventor of the Scalatron), the Australian 31-tone composer William Coates, Erv Wilson, Harold Waage and Glen Prior contributed articles.

(Interval Foundation collapsed in 1991, following a period of extended dormancy. Glasier continues to lecture and perform.)

Scott Wilkinson's *Tuning In* (1987) was the first text available from a popular music publisher to address the history and practice of microtonality at book length.

Computer Music Journal published a microtonal issue in the same year. Among other articles, it featured Douglas Keislar's "History Of Microtonal Keyboards," Clarence Barlow's analysis of many different equal-tempered scales "Two Articles on Theory," and Wendy Carlos' landmark "Tuning: At the Crossroads" in which she discusses the history of tuning, alternative keyboards, and the best ways of obtaining consonance in arbitrary scales using digital synthesis techniques.

From 1985 to the present the author produced compositions in every equal temperament between 5/oct and 53/oct, along with a wide variety of non-octave scales and non-just, non-equal-tempered scales previously unexplored. The author discovered and characterized non-octave scales and non-just non-equal-tempered scales, produced a number of papers for Xenharmonikon including a joint monograph with Darreg (Biases In Xenharmonic Scales), and edited and orchestrated Darreg's 3-volume compilation Beyond The Xenharmonic Frontier. [Darreg and McLaren, 1991; McLaren, 1991; McLaren 1993]

By 1988 new tunings had become so popular that Jim Aiken wrote "Discovering 19-Tone Equal Temperament" for the March issue of *Keyboard* magazine. **[Aiken, 1988]**

Also during this period Morton Feldman produced a number of quasi-improvisatory pieces using various Pythagorean tunings.

Throughout the 80s electronic instruments evolved at a breakneck pace.

From 1977-1980 Jon Appleton helped design the Synclavier, the first completely digital (and completely unaffordable) synthesizer. Subsequently sold to rich rock stars as a method of freezing their assets in a form the IRS couldn't trace, the Synclavier climbed to a list price of over half a million dollars before its parent company went bankrupt and disappeared.

In the meantime, however, Appleton produced a series of striking and beautiful xenharmonic compositions, including the first compositions for digital synthesizer and live orchestral ensemble. Of his pieces *Studies for Digital Synthesizer, Brush Canyon, Degetaru Ongaku* and *Eros Ex Machina* (in the Bohlen-Pierce scale) many are currently available on CD in the CDCM series. [Appleton, personal communication]

In 1978 the Australia-built Fairlight sampler appeared, the first digital sampler of any kind, and probably the first electronic keyboard to cost as much as a house. The Fairlight allowed user retuning via scales of the form Nth root of X.XX, where X.XX < 9.0, permitting composers to explore tunings completely outside the 12th root of 2 (provided the composers were extremely wealthy). **[Burt, personal communication]**

In 1980 Peter Samson designed and built the Samson Box (also known as the System Concept) synthesizer for the Center for Computer Research into Music and Acoustics at Stanford university. This extremely general-purpose synthesizer permitted real-time FM, wave-distortion and additive synthesis with large numbers of simultaneous carriers, modulators, and sine wave oscillators. Completely controlled by software, the Samson Box was capable of producing any tuning system imaginable--and it was soon used to explore non-12 systems, most notably by Bill Schottstaedt. [Schottstaedt, 1985]

In 1981 Rev. 3 of the Prophet Five Synthesizer (first synth to feature a microprocessor) allowed each of the 12 notes to be retuned plus or minus 50 cents, opening the door to a wide range of just intonation and meantone systems. Terry Riley's composition The Ten Voices of the Two Prophets (so-called because of the pair of 5-note Prophet Synthesizers used to realize the piece) appeared on LP shortly thereafter.

In 1983, MIDI (Musical Instrument Digital Interface) became the standard for communcation between synthesizers and computers. Overnight this development revolutionized the still-new field of digital synthesis.

In 1985 Dick Lord rewrote the operating system of the Ensoniq Mirage sampler by hand, allowing the user to retune the instrument to any equal or unequal temperament desired. This was the first retunable instrument ordinary humans could afford. At the time, the Mirage cost $1795, a breakthrough--especially since it offered ordinary composers the opportunity to work in any non-12 scale.

By 1986 the company Grey Matter Response offered an add-on to the DX7 synthesizer allowing the instrument to be retuned into any desired scale with 1/3-cent accuracy.

In the same year Yamaha retaliated with the DX7II, an upgraded FM synthesizer with lower noise, more oscillators--and complete user retunability.

The DX7II was the first affordable electronic instrument with retunability built in at the factory. The resolution: 1024 parts per octave. Subsequent models SY77, TG55 and SY99 enhanced the implementation of Chowning's FM algorithm, with the same 1024 part-per-octave retunability but a different sys-ex implementation.

The Yamaha TX81Z, a four-operator FM module sans keyboard, allowed complete retunability in 768 parts per octave (64 parts per semitone). The FB-01 also used 4-operator FM but allowed microtuning via a unique route: note-on commands tied to series of pitch-bend instructions issued as a continuous system-exclusive data stream. The net result was a synthesizer which allowed complete retunability in 768 parts per octave throughout a 10-octave range!

The DX11 also appeared in the same year. A keyboard version of the TX81Z, it added a separate pitch envelope for each timbre.

Ensoniq followed up with the VFX, retunable to within 1 cent, and the EPS, EPS16+, and ASR-10, all samplers

with increasing bit resolution, ever-larger amounts of memory, and user retunability (again within 1 cent).

By 1988 E-Mu Corp. had climbed on board the microtonal bandwagon with a set of 3 retunable synthesizer modules: the Proteus I, II and III, featuring various sets of sampled looped sounds.

By 1992 most synthesizers allowed the user to adjust at least the 12 notes within the octave: the real choice was now between only-12-out-of instruments and instruments on which every key can be retuned to any desired pitch. Instruments in which only the 12 tones in each octave can be retuned are useless for exploring any scale with more than 12 tones per octave; viz., 13/oct, 23/oct, 41/oct, 31/oct, 53/oct, etc. On any 12-out-of instrument, extensive chromatic passages proceed only through 12 pitches, then require at least 1/2 second of silence before the synthesizer's pitch table reloads from the host computer. This is a limitation that cannot be overcome--it is inherent in the limited transmission speed of MIDI and the minimum necessary size of the sys-ex message needed to send a new tuning table.

In 1991 Ramon Fuller published "A Survey of Equal-Tempered Scales," discussing all the equal-tempered scales between 12 and 96 tones per octave, in the *Yale Journal of Music Theory*. **[Fuller, 1991]**

In the late 80s and early 90s Edward Rothstein began to write militantly xenharmonic book reviews for The New York Times music section; at the same time, Kyle Gann vigorously promoted microtonality in his concert review column for the Village Voice and in his just intonation compositions and analysis for the 1993 issue of Perspectives of New Music. of LaMonte Young's "Well-Tuned Piano." [Gann, personal communication; Gann, 1993, in press]

In 1992 Perspectives Of New Music published a double microtonal issue featuring the round-robin interview "Six Composers On Non-Standard Tunings": Joel Mandelbaum, Easley Blackwood, William Schottstaedt, Lou Harrison, John Eaton and Ezra Sims all delivered their opinions on ways and means of moving outside 12. **[Keislar, et. al, 1992]**

In the introductory notes to the first volume, Douglas Keislar writes:

"...the presence of a sort of popular movement should be noted. ...A few years ago, synthesizer manufacturers started incorporating programmable tuning, allowing popular musicians to investigate the possibilities beyond [12-tone] equal temperament. It should not be too surprising to hear microtones in pop music and jazz... These writings help dispel the perception of microtonality as a strange contrivance touted by impractical eccentrics. Instead they offer a perspective from which the conventional palette of only twelve fixed pitches may seem strangely confining." **[Keislar, 1992]**

Several years earlier, Keislar produced a remarkable Samson Box soundfile in which a Bach prelude is played in a variety of different equal-tempered systems; the effect is exotic and ear-opening.

Also in 1992 the Los Angeles composer Stephen James Taylor became the first to use Erv Wilson 70-note hebdomekontany (Greek for "set of 70 notes") just intonation set in a piece of music. His film score for *The Giving* uses the 70-note array exclusively. **[Taylor, personal communciation]**

Many other microtonal composers, theorists and performers have sprung up in the 80s. Too many, in fact, for any one person to be familiar with all of them. From the MIDI composer Carla Reisch to the generalized keyboard designers James A. Davis and Larry Hanson; from the Sweelinck Conservatorium xenharmonist Alcedo Coenen to the Bay area just intonation doyens Carter Scholz, Robert Marsanyi, David Doty and Henry Rosenthal of the nationwide Just Intonation Network; from the 7- and 15-tone acoustic composer Clem Fortuna to the 10-tone composer Gary Morrison; from the German 17-tone community including Georg Hajdu, Clarence Barlow, Carola Bauckholt, Kaspar Johannes Walter; from 19-tone virtuoso guitarist Neil Haverstick of Colorado to CCRMA/*Zentrum fur Kunst & Medientech*'s multitalented Johannes Goebel, inventor of the room-sized microtonal instrument the SubBassProtoTone; from 19-tone guitarist Jeff Stayton to the Harvard University Science Center microtuning guru Benjamin Denckla; from the Boston Conservatory's inimitable Joseph Gabriel Maneri and his microtonal ensemble to meantone enthusiast Douglas Leedy, whose article "Notes On An Overlooked Temperament" appeared in the 2nd microtonal issue of *Perspectives Of New Music*; from Mexican computer music virtuoso, ethnomusicologist and microtonalist Arturo Salinas to the Ben Johnston scholar and extended just intonation practitioner John Fonville of the UCSD Center for Music Experiment...many, *many* important figures have received short shrift in this history.

There's no help for it.

As the end of the century approaches, the once-fringe practice of microtonality has become so widespread and so commonplace that it will soon be appropriate to ask *Which scales do you work in?* and *What's your favorite?*

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