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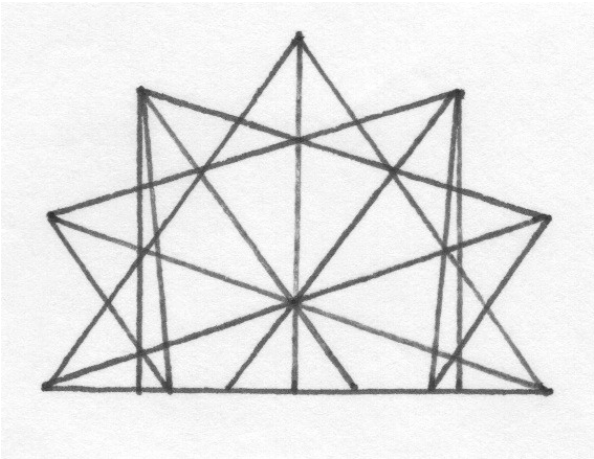

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A SHORT HISTORY OF JUST INTONATION TUNING CULTURE[1]

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The use of Just Intonation (JI or simple ratios) as a musical tuning norm has a very long and illustrious history. However, this history is also rather complex. I cannot hope to give but the barest outline of an overview in this abbreviated format--it deserves a book! Nevertheless, an essay is a valuable exercise in condensed presentation. But inevitably it has its price. My interpretations of the historical data are sometimes based on long strings of circumstantial evidence, since this is all the information available. Consequently, it is only possible to present a fraction of the arguments which support my conclusions within this brief context. The reader should not forget that this is only one person's version of the 'most likely story.' Yet in spite of these uncertainties, it is my duty to defend this long-researched position with a healthy vigour. Forgive me if the tone of this paper sounds a bit dogmatic.

Now, with my apologies done, I propose to present some prominant aspects of this ancient and extensive history. It is here rendered into six sections of unequal length. Each section has a title whose meaning will become apparent. Above all, I hope to show that, given a long-term perspective, **JI has been the dominant norm throughout much of world music history.**

THE ANCIENT PLURALISM

Even if we set aside the compelling evidence for a very ancient Egyptian elder culture which built the Sphinx, it must still be admitted that civilization is very old. The earliest known literate, urban, socially-stratified, hieratic city-states appeared roughly around 3100 B.C.E. in Sumer (Iraq). However, such city-states as Eridu already had long roots as 'town' cultures going back to before 5500 B.C.E. Roughly contemporary with developments in Sumer, we witness the earliest multi-city unified empire-state in Egypt. Within 500 years there were also literate city-states beyond the 'golden crescent;' indeed, they sprouted seemingly like mushrooms from Crete and Cyprus in the Mediterranean west across Syria, Kurdistan, Anatolia, Iran, and the Indus (Pakistan, Afghanistan, north India). Somewhat later civilization also appeared in China. The heart of this huge ancient culture zone must have been somewhere around Anatolia-Kurdistan-Iran.

The literary evidence indicates that all of these ancient high civilizations had complex music cultures with varieties of musical instruments. Moreover, their music was closely tied to magic, religion, ritual, medicine, and cosmology. The standard orthodox scholarly opinion that the old Mesopotamian music cultures must have been 'primitive' is not at all realistic. Such a viewpoint necessarily imposes a crude, facile, and inappropriate linear evolutionism on complex cultural issues. On the contrary, the circumstantial evidence indicates the presence of a peculiarly intensive and developed musicality. Music was apparently their most prized art form. It is highly unlikely that these strong musical cultures did not contemplate and explore issues of musical tuning.

Although some orthodox scholars will admit that the ancient musicians must have known the rough relation between string-length and pitch, they would claim that the knowledge of musical ratios was not *quantized* until the classical Greek era--that is, until quite late in ancient history. They would claim, for example, that musicians tuned their octave only 'by ear,' not knowing that the octave could also be found by touching the middle of the string and/or placing a movable bridge at that point. This may be the case, but I doubt it. Either way, tuning 'by ear' tends to reinforce the same simple ratios that one finds on a monochord, so that there is certainly no natural conflict between the 'ear' and monochord approaches. They support each other.

The ancient cultures most definitely had a good 'ear,' since they distinguished enharmonic intervals. We know this from various writings about music and the evidence of ancient music notations. The most ancient tablet revealing a musical notation yet found in the Near East, from the second millenium B.C.E., already indicates a knowledge of the diatonic and chromatic scales, if only in a form of 'solfeggio' which does not specify pitch exactly. However, I would contend that this does *not* mean that they knew little about tuning. As is often the case, the notation may serve merely as a device for assisting memory in performance and not as a record of exact tuning procedures, much like systems of solfeggio still in use in Asia today. Yet such notations afford clues to the high level of competence displayed by these cultures.

Some orthodox scholars will allow that the ancient Babylonians knew the 3-Limit ('Pythagorean') approach to the diatonic scale, but *not* the 5-Limit version of the same harmony. (If the terms 3-Limit and 5-Limit leave you baffled, see Note #2). In fact, Greek sources contend that the 3-Limit diatonic scale was the oldest tuning. But it is highly unlikely that musicians could know about 3-Limit ratios without also knowing about 5-Limt ratios (indeed, even the n-Limit). It's a bit like stating that someone, who admittedly knows how to count, can count to 10 but not to 20. The late Greek evidence probably just indicates that they may have *preferred* a 3-Limit harmony over a 5-Limit harmony at the time and place of writing.

Anyone who works with JI tuning soon finds that we have a choice between 3-Limit and 5-Limit harmonies when we erect a diatonic heptad (seven tone) scale. One must also admit that the 5-Limit is (and, I believe, has always been) the true structural heart of JI tuning. The 3-Limit is an essential subset of the 5-Limit, and the 7-Limit is a rather esoteric extension of it. I would contend that, in all of these ancient cultures, 5-Limit JI (and its subsets and possibly extensions) was indeed the source of ancient tuning norms.

How do we know this? Although there is very little direct evidence, there is much indirect circumstantial evidence. In order to present my case, I must introduce the ancient medium for setting tunings--the monochord.

Although the vast majority of western music scholars still follow the orthodox theory that the monochord was invented by the Greeks in roughly 500 B.C.E., it is almost certainly *much* older. We have pictorial evidence of fretted stringed intruments from ancient Egypt, Babylonia, India and China. The earliest pictures of dedicated monochords in fact came from China. When one thinks about it, every fretted instrument is an application of the monochord principle. In essence, this principle is simply **a calibrated decision over fret placement**. Either the frets were placed haphazardly, or there was some systematic thought given to their proper placement. I assume that the ancient tuner was just as intelligent as we are, and that his/her 'ear' was just as sensitive to pitch differences, maybe even more so. Whether the tuner was in China or Egypt, he/she would encounter the same psycho-acoustical phenomena. Consequently, the monochord principle was probably discovered repeatedly in varying times and places. The existence of fretted instruments is certainly much older than the Greek civilization. We can safely conjecture that the monochord 'tool' was the universal ancient method for exploring the world of musical ratios.

This situation may seem a bit peculiar to most modern explorers of JI, for whom the Harmonic Series is primary. For example, we moderns would derive the Major Triad from the Harmonic Series componants 4:5:6:8 (i.e. C E G C) as a rising scale of frequency relations. Since we do not experience the Sub-harmonic Series directly in nature, we tend to view the concept of the Sub-harmonic Series solely as the theoretical reciprocal of the Harmonic Series, since the two are not individually symmetrical. The phenomenal world presents us with objects vibrating in patterns derived from the Harmonic Series. Naturally, from this series we derive the musical ratios.

But a monochord gives the same ratio patterns as derived from the Sub-harmonic Series. In this situation, the numbers increase in size as the pitch gets lower. **The ancient norms were derived from the monochord.** Thus the same Major Triad mentioned above would be presented as 15:20:24:30 (i.e. C G E C), a falling scale on the monochord. In this case, the monochord string has been divided into 30 equal-sized (arithmetical) units. Position 15 is thus the middle of the string, and we have here an octave sequence bound by the double 15:30. The ancients acknowledged the harmonics as secondary and the reciprocal to the monochord patterns. Of course, the one always implies the other, since frequency is inversely proportional to wavelength. Multiplication implies division. The ancients were certainly alive to the implications of reciprocal relations.

Throughout history, there have always been two readily available 'non-technological' methods for setting just ratios on strings. First we have the HARMONIC METHOD, in which one compares harmonics between strings, carefully eliminating beating between the harmonics--the comparison between frequency relations. Second, we have the ARITHMETIC METHOD, in which one sets up a falling scale on a monochord by dividing the string into a specific number of arithmetic divisions. The existing evidence indicates that the second method has historical precedence.

It is important to get used to the monochord approach, if one wishes to understand the ancient mindset. The arithmetic involved is surprisingly simple and archaic. It includes the search for least common multiples in order to insure whole-numbered sequences of simple ratios, as well as the classification of numbers into 'families' through prime factors. This sort of arithmetic appeared already exquisitely well developed in the *earliest* mathematical texts of Sumer.

The Sumerians, and their cultural heirs, the Babylonians, used number base 60 as well as 10, and had a peculiar focus on 5-Limit numbers. ($60 = 2^2 * 3 * 5$). Number base 60 is ideal for setting 3-Limit and 5-Limit scales on a monochord. In addition, according to some musicologists, the Babylonians had the most complex culture of ritual temple music ever encountered in history. They used whole 'orchestras' of harps and lyres. Their music culture was certainly not crude. In fact, most of our earliest pictures of string, wind, and percussion instruments came from this region. It seems highly unlikely to me that they did not consider matters of tuning strings. Moreover, their principal gods were identified with musically important 3-Limit and 5-Limit monochord numbers.

Although we have no direct evidence of musical tunings from ancient Egypt, we know that they had an advanced music culture, involving harps of all sizes among other strings, winds, and percussion. How likely is it that they were ignorant regarding musical tuning? The peculiar ancient Egyptian method of doing arithmetic by repeated doubles is usually dismissed as 'primitive' (a word with offensive pejorative connotations) by modern historians of mathematics. Yet this very technique of exploring repeated doubles is perfectly suited to the monochord context, as we shall see below. The Egyptian civilization produced amazing artistic monuments which display an advanced knowledge of spacial ratios and proportions; yet they, like the other ancient civilizations, prized music as the most spiritually significant art form. This was understandable, since the monochord afforded a ready and perfect example of the establishment of order out of chaos. Hence, the numerical architecture of harmony became one of the main sources of, and justifications for, ancient speculations concerning cosmic creation, metaphysics, and sympathetic magic.

I must emphasize the strong association of the monochord with sympathetic magic, as a justification for the notion of 'affinities' (consonance-dissonance, love-strife) and related associations. The connection between tuning work and magic is not at all far-fetched, especially considering the powerful effects of music over people, even today. I would assume that ancient peoples were even more 'influenced' than we moderns, since their cultures were less 'visually oriented' than ours. Music was undoubtedly a powerful tool of theurgy. To set up a harmony was to conjure up the gods--to *make them live*. The procedure and its magical implication is akin to alchemy. Not surprisingly, we see similar symbols in the language surrounding ancient music, magic, alchemy, and medicine.

The monochord procedure sets up a hierarchy of 'affinities' in the number field. Certain divisions are musically more significant than others, since strong, musically consonant harmonies are a comparative rarity in the vast and endless sea of dissonant

ratios. One can explore these various hierarchies rather objectively, since the inherent arithmetic is unambiguous and demonstrable. I have spent many years exhaustively mapping this branch of applied arithmetic to a high resolution. Amazingly enough, I found that the most significant numbers from a *purely musical context* also turn out to be the very numbers most emphasized from the standpoint of cosmology. My findings largely corroborate and confirm the research of professor Ernest G. McClain.[3] Although there may be some shift of emphasis between us, as well as some differences in the details, the overall picture is the same. **Important monochord numbers are always important cosmological numbers in ancient cultures.**[4]This situation says to me that the ancients had a good working knowledge of monochord procedures and arithmetic.

A more conventional scholar would say here that this 'coincidence' is no proof that the ancients had done their monochord arithmetic. The question, of course, hinges on what constitutes proof. Be that as it may, in my experience, the vast majority of scholars who make such pronouncements have themselves only the most superficial familiarity with hands-on monochord work and its associated arithmetic. Moreover, following a model of progressive cultural evolution, they generally assume that the ancients knew *less* than they know. Historically, the monochord has become marginalized, so that most modern scholars do not appreciate its true importance for ancient cosmology.

We must admit that no one knows, or will ever know, who first invented the monochord, or where and when. My own conjecture of the 'most likely' story centres on the second wave of the neolithic revolution (began roughly 6500 B.C.E. in Kurdistan). It was during this neolithic era (between 6500 and 3200 B.C.E.) that the planting calendar systems were codified through systematic observations of the heavens. Moreover, the development of animal husbandry, plant breeding, large-scale irrigation systems, complex architecture, and the early smelting of metals were developed. During this 'heroic age' of the development of town cultures, we also see the evolution of highly polished and artistic pottery with abstract themes based on the four-pointed star and spiral. In all of these activities one sees a new *actively interventionist relationship with nature*. The simple yet pregnant measurement of the monochord fits well into this scenario.

Perhaps the neolithic monochord principle was discovered through the much older palaeolithic invention of the hunting bow. Whatever, one can safely conjecture that the division of the monochord was one of the earliest truly scientific experiments ever to be accurately calibrated, rivalling the establishment of the multiplication table and the measurement of the cycles of the sun, moon, and planets. Indeed, it was probably the same people doing all of these researches. These same people preserved their tribal histories through telling stories and singing song-poems about the gods. Their singing was often accompanied by stringed instruments which must be tuned! Thus the whole context of early science was musical.

Although we do not have direct evidence of tunings from this 'heroic age' before writing, we do have archaeological evidence of religious-cultural symbols later closely associated with the monochord. Indeed, there is an overall confluence between the

symbolic descriptive languages regarding music, magic, astronomy-astrology, alchemy, medicine, and religion in the ancient world. Creation stories are particularly rife with monochord-related symbolism. Foremost among these musical metaphors, the following stand out: First, the sexual or fertility theme, including the Sacred Marraige and the generation of 'offspring'--in general, the relations between the gods. Second, the Elements or Sacred Roots (Seeds), the Sacred Plant or Garden, which is the firm foundation for the generation of the universe. Third, the universe itself as an egg-shaped or spherical 'cosmos' with Earth in the centre surrounded by the planets and stars. And fourth, the Sacred Mountain in the centre of the world, from which flow the four rivers.

In order to understand the musical relevance of these images, we must turn again to an examination of the monochord, and its mystical-magical arithmetic.

In all ancient references to numbers, odd numbers are male, and even numbers female. Marraiges between numbers by multiplication generate 'children' as least common multiples. This sexual metaphor is clearly seen in late ancient history through the Greek concept of the *Genera*. Diatonic harmony generates chromatic harmony, which generates enharmonic harmony. All of these harmonic 'worlds' are ultimately generated from the One, the initial open string of the monochord. Like monochord procedures, ancient cosmology was inherently emanationist and hierarchical.

As an example of the procreative sexual metaphor, let us generate a 5-Limit diatonic tetrachord, say the tetrachord 15:16:18:20 (i.e. C B A G). We can derive this sequence by interpolation into the 15:30 sequence presented earlier. Alternatively, we can derive it directly from the tetrachord ratio 3:4. For the ancients, whether in Greece or in India, the tetrachord was the essential scalar fragment. It first arises in the elemental division 3:4:6 (i.e. C G C). In Greece, this musical fourth 'frame' was called the *Meson Tetrachord*, since it began on the *Mese* (middle of the string) and proceeds downward in pitch. The 3:4 frame is the 'fixed' portion of the scale, which is then filled in by the two 'mutable' elements. Notice that 3 is male and 4 female--the king (father) and queen (mother) of the tetrachord. By expanding the numerosity of the 3:4 to 15:20 (multiplication by 5), the new elements 16 and 18 are caught in the 'net;' that is, they are allowed to become members of the set (family). These numbers (tones) are then 'offspring' of the parental 3:4 ratio, which is capable of 'birthing' a variety of musically interesting children.

In the same way, the various possible octave scales are all children of the parental 1:2 ratio. This key ratio is the first logos, the cyclical identity which generates the expanding vortex of relations. In any monochord division, there will always be a smallest number (in our example 15) which requires the other numbers to be doubled a few times, (in Egyptian fashion), in order to express a simple whole-numbered sequence. Thus 16 comes from 8, from 4, from 2, and ultimately from 1. Monochord sequences define patterns of interval relatedness. Therefore the image of family relations is highly appropriate to harmony. The ancients expanded this metaphor to include the *polis* or

community of relations, the city being an excellant example of relatedness between disparate elements.

Why odd numbers are male and even numbers female becomes more apparent when we examine the very first four archetypally simple monochord divisions. These divisions have supreme importance as a source for symbolism, since monochord arithmetic is based on *emanation from first principles*. From unity, some diversity emerges in an orderly manner. These are the 'ur' divisions or the ***Elemental Monochords*** in which the mese number is consecutively 1, 2, 3, and 4. From these divisions naturally arise the ubiquitous symbols of the Elements or Sacred Roots (Seeds) in their proper sequence.

We are given the open string before the movable bridge is applied. This is the ONE, the Monad, the reference pitch (here arbitrarily C), the source, and the Element FIRE (or Heaven, Sky). The placement of the bridge in the middle generates the foundational monochord sequence 1:2 (i.e. C C), the falling octave frame, the Mese, the Element EARTH, the goddess in the middle, the Dyad, the power of the prime number TWO. Heaven and Earth have priority as Elements or Roots. They together generate the 'medial' Elements Air and Water by mediation. All of the many possible scales of JI harmony exist as a result of the dance between Heaven and Earth (1:2), the microcosm within the macrocosm of the pitch continuum. The Dyad, as cyclical identity, is the mother-womb (matrix) of the expanding network of harmonic relations. Hence even numbers are naturally female.

The following octave division yields the octave sequence 2:3:4 (i.e. C F C). By the power of the double as cyclical identity the 1:2 has become 2:4, so that between these two female numbers the odd prime number THREE is born as the *Arithmetic Mean*. This is the first male number, since the ONE is beyond gender, the high god who is omnipresent in every sequence. (Every number is divisible by One). The number THREE is the Element AIR, the number forming the intervals of power, the arrow, the hero-male number who marries the Dyad, thus differentiating the field of relations, the Demiurge, the seminal source of potentially endless multiplicity. In this procreative relationship, odd numbers (especially primes) are active componants, and hence male.

In the following division, we have 3:4:5:6 (i.e. C G Eb C), the foundation triad of ancient harmony. Here the 2:3 has become the female 4:6 in order to give birth to the 'child' male prime number FIVE as the Arithmetic Mean. The number FIVE yields the intervals of beauty and emotion, and the Element WATER. We have now generated the trinity of number powers (2, 3, and 5) which are the primary masks of the One. The 3:4, as we have already seen, is the Meson Tetrachord frame, the axis of the scale.

The division 4:5:6:7:8 (i.e. C Ab F D^{+} C) yields the male prime number SEVEN, the esoteric Element AETHER, which increasingly rose to prominance in the later part of ancient history. Finally, as an arbitrary end to our primary divisions, the sequence 5:6:7:8:9:10 yields 9, the first odd number which is *composite* or not prime. Hence there is no new Element or dimension here. This situation creates a natural demarcation in the

overall procedure. It is thus inevitable that we end the 'ur' sequence at the double 4:8 in the generation of the root Elements. In fact, most ancient cosmologists recognized four Elements (i.e. 5-Limit harmony), but some employed five Elements (7-Limit harmony). These Elements are the true roots (seeds), the 'grandparents,' the prime factors which generate, through their composite number 'children,' the world (cosmos) of practical musical tunings.

This 'metaphysically primary' monochord 'ritual' can be summarized arithmetically through the application of the two musical *Means*--the ARITHMETIC MEAN which we have just seen demonstrated on the monochord, and its reciprocal, the HARMONIC MEAN, which is demonstrated on the Harmonic Series. The arithmetic involved is absurdly simple but infused with supreme mystical significance. To find the two Means between any ratio, double the numbers and insert the middle term. Thus, for example, the Harmonic Mean (HM) and the Arithmetic Mean (AM) of the octave (1:2) are 2:3 (G) and 3:4 (F) respectively. The former is demonstrated in the Harmonic Series fragment 2:3:4 (i.e. C G C in a rising scale), and the latter is demonstrated with a monochord as sequence 2:3:4 (i.e. C F C in a falling scale). The ratios 2:3 and 3:4 are the foundation ratios of 3-Limit harmony, the intervals of power, the perfect consonances.

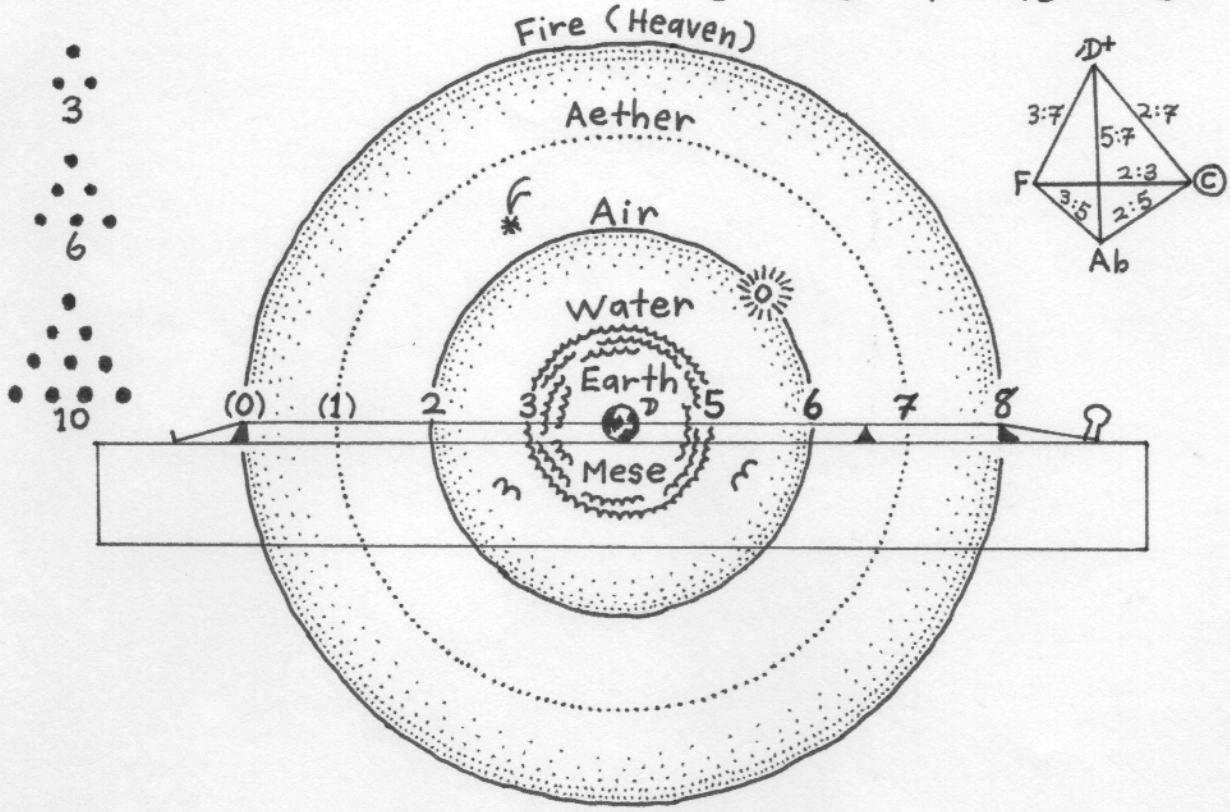
The Means of the musical fifth (2:3) are 4:5 (E) and 5:6 (Eb), the intervals of beauty which form the foundation ratios of 5-Limit harmony. The Means of the musical fourth (3:4) are 6:7 (D#) and 7:8 (D^{+}), the intervals of mystery, which form the archetypes of 7-Limit harmony. To finish our basic sequence, the Means of the musical major third (4:5) yield 8:9 (D) and 9:10 (\D), which are the important whole-step intervals characteristic of 5-Limit JI harmony. We can see that the successive 'levels' of the architecture of JI harmony, 3-Limit, 5-Limit, and 7-Limit, are generated by our 'ur' sequence. For various reasons which will become apparent, the monochord division 1:2 was associated with the *point*, the division 2:4 with the *line*, the division 3:6 with the *triangle* or surface, and the monochord 4:8 with the *tetrahedron* or solid dimension. This PROGRESSION OF MEANS forms the core image of ancient metaphysics.

The monochord division 4:8 is, of course, a close descendant of divisions 2:4 and 1:2, through doubling. In this, the canonical ELEMENTAL MONOCHORD, we see the musical source and/or justification for the ancient image of the wider cosmos (see diagram). The universe is metaphorically a stretched music wire. The Earth (4 which comes from 2) is in the mese (middle) position, surrounded by the circle or sphere of Water (5), then Air (6 comes from 3), then the optional Aether (7) which was usually and naturally equated with either Air or Fire.[5] Surrounding all is Fire or Heaven or Sky (8, derived from 1), which is the circumference circle of the cosmos, the fixed realm of the stars, the initial open string. This sphere is an egg, pregnant with potential life. The Earth is its yolk, the goddess who gives birth to the further multiplicity of alternative scales (gods).

There are many ancient references to the Elements or Roots as the Sacred Plant. I will use the lotus as a typical example, omnipresent in ancient iconography from Egypt to

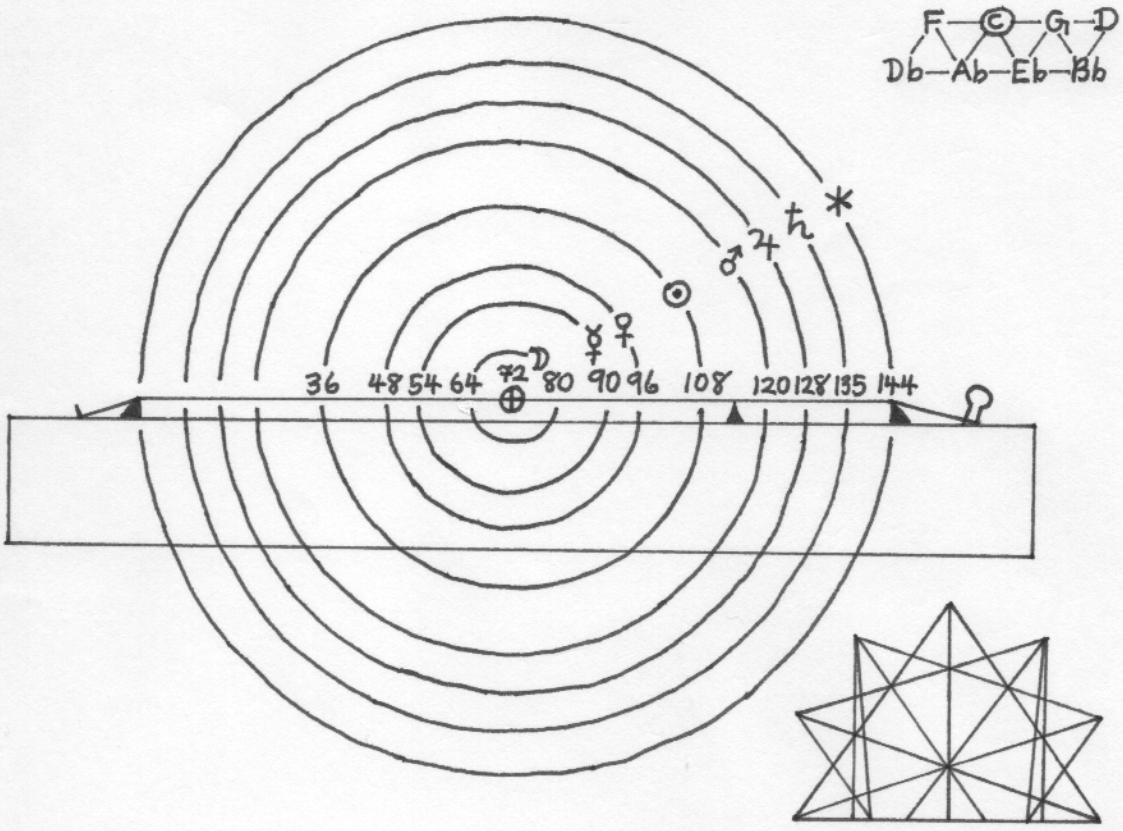
The Elemental Monochord:

4	:	5	:	6	:	7	:	8
C		Ab		F		D+		C



A Planetary Monochord:

⊕	☽	☿	♀	☉	♂	♃	♄	✱
72	80	90	96	108	120	128	135	144
C	Bb	Ab	G	F	Eb	D	Db	C



India. The lotus symbolizes the cosmos, since the original seed came from Heaven, its roots are in the Earth, its stem in Water, and its flower in the Air catching the rays of the Sun (Fire). The essential image is one of organic growth from Earth (the middle of the string which is always the starting point of the scale) towards the Heaven (Fire or the open string).

The origins of near-eastern fertility religion, using images of the goddess and the god who generate the abundance of nature, run very deep into the neolithic past. So does the notion of the four Elements, through the image of the cross and the spiralling cross. The ancient city-states conceived of themselves as reflecting the cosmic musical order through the mesocosm of the temple, the heart of the city as sacred space, and the microcosm of the individual. This is understandable, since the monochord was the simplest easily verifiable metaphor for order-in-general, and especially temporal order. This may also help explain the peculiarly close relations between important monochord numbers and ancient calendar systems.[6]

Given this confluence between music and cosmology, it is quite understandable that the ancients sought to integrate the planets into this universal scheme. Since there was no available method for measuring the physical distances between the seven planets, they naturally assumed the numerical distances to be based on the relations displayed by the most significant of diatonic harmonies. Because the egg-shaped cosmos consists of eight concentric rings around the Earth in the middle, it must form the 5-Limit Diatonic Ogdoad (eight tone) harmony--the monochord division 72:144 (see diagram). This monochord has such over-riding significance within a purely musical context that it was projected onto the cosmos.[7] The Egyptians recognized the Ogdoad of eight greatest gods. We have also noted that the Elemental Monochord is the division 4:8. In addition, the ratios involving numbers up to eight form the only musical consonances, the ratio 7:8 being in the border zone between consonance and dissonance. The number eight is a key harmonic number which keeps re-surfacing within various contexts, for example below.

The ubiquitous image of the Sacred Mountain is also quite musical. This is the locale where the ONE high god descends (emanates) to meet or generate the multitude. The Egyptians built pyramids, the Babylonians ziggurats, partly as expressions of this image. In order to see the musical source, we must look a little more closely at our primary, simplest monochord divisions. Here is the same PROGRESSION OF MEANS which was outlined above. Now it is presented in a small table with some additional information:

Source Ratio	HM	AM	Relation	Significant Factors	Genus
1:2	2:3	3:4	8:9	$8 * 1 : 3^2$	Diatonic
2:3	4:5	5:6	24:25	$8 * 3 : 5^2$	Chromatic
3:4	6:7	7:8	48:49	$8 * 6 : 7^2$	Enharmonic
4:5	8:9	9:10	80:81	$8 * 10 : 9^2$	(Commatic)

The information in the first three columns has already been presented in generating the Elements. The fourth column, marked *Relation*, gives the interval relation between the HM and the AM. The 8:9 is the Diatonic Wholetone. 24:25 is the small, Chromatic Semitone. 48:49 is the 7-Limit Enharmonic Semitone. 80:81 is the Syntonic Comma. For this and various other reasons which I cannot pursue here, this PROGRESSION OF MEANS is the ultimate source and justification for the ancient musical notion of the *Genera*: Diatonic, Chromatic, Enharmonic. The sequence can be extended to include the Commatic, but this is a sort-of 'atomic' realm, since, according to all ancient sources, enharmonic intervals (roughly 'quarter-tones') are the smallest to be considered independant scalar elements.

To go back to the image of the Sacred Mountain, the fifth column factors the 'relation' ratios in a significant way. The numbers on the right side of the ratio form the series of odd squares. The numbers on the left form a significant series emphasizing (again) the number eight. The series 1, 3, 6, 10...is the *Triangular Number Sequence*, whose geometrical image is the *Tetractys* or the 'triangular mountain.'

The fact that the image of nested equilateral triangles should be implicated in the very core of harmonic architecture should come as no surprise. For the triangular number sequence defines the quantification of relatedness between musical events. For example, two tones have one interval or relation between them. Three tones have three relations, four tones six relations, five tones ten, and so on. For this reason, among others, a triangular-hexagonal matrix is the most appropriate visual image for a 5-Limit matrix of relations. It is this matrix of relations which was implied by the cryptic metaphysical progression *point* (the empty octave or 2-Limit harmony), *line* (3-Limit harmony as a line of fifths-fourths), *triangle* (5-Limit harmony as a two-dimensional triangular web of just triads), and *tetrahedron* (7-Limit harmony requiring a third or 'solid' dimension). According to the (admittedly late) evidence of Aristoxenus, the Greek harmonists used "closest-packed" diagrams of pebbles as memory devices to define musical tunings. The term 'close-packing' *means* a triangular-hexagonal grid on the two-dimensional plane. The image of the Sacred Mountain comes from this matrix, and matrix thinking in general, which was prevalent in the ancient world.

There is much more to ancient monochord symbolism than the highlights presented here, but I wish mainly to convey the picture that the roots run deep and have many facets. **The numerical architecture of JI tuning had a profound impact on ancient cosmology.** Not only were the ancients knowledgable about this architecture, but they were also alive to its relevance for cosmological speculation. We can safely assume that they were more sonically than visually inclined, in comparison to modern cultures which have a much more visual sensory orientation. Consequently, a musical conception of reality had more meaning for them.

Inevitably, all of these musical models and speculations were absorbed by the Greek culture which flowered late in the ancient period. According to their own evidence,

Greek cosmology developed out of the 'stress' between the analog and digital experience of harmony. The issue brings up various aspects of harmony which were only expressible through paradox and other forms of 'revelation.' The resulting 'rethink' of the old musical model led to the eventual fragmentation of the old unity, so that the various disciplines of cosmology went their own way, with disastrous affects on the ancient cosmic paradigm. The musical model would increasingly be de-valued, and, in the long process of time, highly distorted and almost forgotten.

The more conservative digital camp championed and sanctioned the old model in a typically Orphic manner, or else tried to reconstitute it in esoteric ways. Into this camp I put, for example, Pythagoras, Empedocles, Philolaus, Archytas, and ultimately Plato. The more radical and progressive analog camp sought to significantly amend aspects of the old paradigm, or even transform them altogether. Into this camp I would put Anaximander, Anaximenes, Parmenides, Anaxagoras, Democritus, and ultimately Aristotle. However, we must not suppose that these two camps are totally mutually exclusive. Indeed, some of the most profound and musical of the cosmologists, e.g. Heraclitus, straddle both camps. This simple scheme is really a continuum and not a black-and-white dichotomy, for a generally cohesive movement whose roots probably stem from Egypt.

The radical agenda of early Greek science was set by the earliest philosophers, Anaximander and Anaximenes, who undoubtedly were the most influential of the early cosmologists in the Greek west. To a certain extent, the rest of Greek cosmological history was a response to the vision posed by these two Milesians.

Anaximander exhorted us to face the *Apeiron* or *Apeiros*, a concept inextricably paired with *Peras* at the heart of ancient philosophy *and* monochord work. Peras means that which is definite, limited, that which can be defined, in other words, the digital realm of harmony and number. Apieron is that which cannot be defined, the infinite, the unlimited, that which is beyond measure, the analog perspective. The art of musical tuning can be seen as a balance between these two opposing forces (love-strife). The scale must have some variety (Apeiron), but it must also be strictly defined or limited (Peras). The concept of 3-Limit and 5-Limit harmony is itself an aspect of Peras. In the following generations, the Pythagoreans identified Peras with the Monad, and Apeiron with the Dyad. This is understandable in that the Dyad is the womb-source of the vortex of number complexity, the 'spinning out' or weaving aspect of the double. But any scale, no matter how complex, if it is defined, is an expression of Peras (the definite). Such scales co-exist as a *cosmos* (a Whole) ruled by *logos* (ratio) and initiated by some intentional understanding (*Nous*). If the pitch continuum is infinite, even between a semitone, then all 'being' comes from or is selected out of the Apeiron. This was the radical truth, with all of its implications for the musical notion of justice, presented by Anaximander.

Anaximenes, absorbing this radical perspective, recommended the replacement of the ancient Elements altogether, since the sequence of numbers, even prime numbers, as 'seeds,' is infinite. He proposed to replace the discrete numerical scale between Heaven and Earth with a continuum characterized by 'condensation and rarefaction;' that is, it has

maximum density on the Earth side, and maximum rarity on the Heaven side. Such a scale is reminiscent of a logarithmically tempered scale in which the frets are closer together toward the mese. The Elements are to be represented by 'qualities' originally associated with the Elements, but now dualistically polarized on the continuum: Heaven (hot, dry, rare), Earth (cold, wet, dense). The diverse Elements are to be replaced by one *quasi-element*, AIR, the most appropriate one, since 5-Limit ratios can be closely simulated (allowing the schisma interval shift) in an extended line of 3-Limit ratios. Hence Air (extended 3-Limit harmony) is the best single Element to replace the manifold of prime-number Elements. Anaximenes' 'reforms' ultimately won out, in that, historically, extended 3-Limit tuning tended to replace 5-Limit tuning by the close of the ancient world.

Anaximenes' cosmology reminds one suspiciously of temperament thinking--and this is right! **The Greek cosmologists explored temperament through the Geometric Mean and other irrational ratios.** However, I must stress that this research was always rather esoteric, and most likely had little influence on the wider music culture. Most musicians probably continued to tune the same way that they always had, in varieties of 3-Limit and 5-Limit JI scales.

If we return to our 'ur' monochord sequence yet once again, we can see why the most significant (i.e. the sweetest, most useful) systems of equal-temperament suggest themselves from the progression 8:9, 24:25, 48:49, and 80:81 (Diatonic, Chromatic, Enharmonic, Commatic). The correspondance between musical Genus and the good temperaments is based on the sizes of the respective step intervals, as follows: The Diatonic Genus (8:9) is associated with 12-et, a system resolved into diatonic semitones and wholetones. The Chromatic Genus (24:25) is associated with 19-et, which is a system resolved into steps of tempered chromatic semitones. The Enharmonic Genus (48:49) is associated with 31-et, which is a system resolved into steps of enharmonic semitones or 'quarter-tones.' And the 'Commatic' Genus (80:81) is associated with 53-et, a scale of tempered commas. Without any doubt, these four tempered systems are the best available options. In addition, they bare a peculiarly close relation to the old triangular matrix. 12-et is strongly oriented along the 3-Limit line of fifths. It is a tempering of this 'region' of the matrix. Similarly, 19-et and 31-et orient strongly along the other two axes of the tri-axial matrix. 53-et, meanwhile, is an 'atomic' realm subsuming or containing the others.

In addition, there is a strong association between these key tempered systems and the irrational prime number roots of Sacred Geometry (the square roots of TWO, THREE, and FIVE, which are the primary geometrical constructions from the ONE). For various reasons relating to harmonic structure, the square root of Two is strongly associated with 12-et, the square root of Three with 19-et and 53-et, and the square root of Five with 31-et. Indeed, the ratio Two to the square root of Five, which is the Geometrical Mean of the 4:5, is the *meantone* itself, and is used in the classical construction of the Golden Section ratio (beloved of the Pythagoreans). Thus we see a complex interplay between esoteric geometry and tempered harmony.

There is much indirect evidence for the active exploration of temperament in the Greek writings. There is even some direct evidence. For example, we have Philolaus' assertion that the 8:9 wholetone is naturally divided into nine commas. This strongly implies the 53 comma scale. Most orthodox scholars maintain that his nine commas are a red herring, since they can be assumed to be of unequal size. This may be so, but the other fragments of Philolaus also exhibit an advanced understanding of harmony, so that I am willing to give him the benefit of the doubt. Roughly contemporary with Philolaus in the 'west,' the comma (sruti) was hailed as the atomic unit of scale construction in the Natyashastra--the earliest text of India to discuss musical tuning. The first explicit published description of the 53 cycle, however, came from China. It is only natural that the first 'logarithmic-style' scale should be a scale of commas, since practical just intonation divisions soon lead to comma-juxtaposed intervals. Out of these possibilites the ancient tuner made choices; hence an underlying scale of commas. But the notion that this scale should consist of equal-sized (tempered) commas was definitely esoteric.

The clearest, most direct late evidence of the use of temperament was in the writings of Aristoxenus, a pupil of Aristotle (about 310 B.C.E.). He divided the wholetone into 12 'parts' rather than just ratios, in the typically logarithmic style associated with tempered fretboards. Later, Cleonides converted these verbal descriptions into the 30 parts of the tetrachord, in other words, 72 parts to the octave or 72-et. In fact, Aristoxenus occasionally expresses half parts, so that he really requires 144-et. Although 72-et and 144-et are decent systems, I can't help but think that his motives were more esoteric than practical, given his connections to the old Pythagorean school, and given that the just monochord 72:144 was the principal old cosmic planetary division.

The 'pre-socratic' creative search to integrate paradoxical aspects of music into the old cosmology was largely resolved in the exquisitely evolved musical cosmologies of Anaxagoras and Democritus, representing the very peak of Greek cosmological thinking. Later ideas were heavily influenced by these two. However, after 400 B.C.E., Greek culture began its slow degeneration. Unfortunately, most of our information on the early cosmologists is derived from late sources hundreds of years removed from the period, and usually not so knowledgabe regarding musical issues. Even Aristotle is not always so trustworthy a reporter. Plato is rarely direct or easy. He is almost always esoteric or veiled, and makes much use of the paradoxical approaches pioneered by Heraclitus, Parmenides, Zeno, and Philolaus. Nevertheless, there is much of value in Plato if one has a grounding in the underlying monochord concepts. In several places he alludes to the point, line, triangle, tetrahedron progression with its elemental divisions, most clearly in the *Epinomis*. He also refers to a number of significant monochord divisions, both just and tempered, using the old city-state metaphor. The influence of musical tuning on his metaphysics is enormous, even though much of it can be traced to his predecessors, whom he rarely acknowledges.

After 400 B.C.E. we see a general cultural decline, especially in the music culture. Plato himself noted it and offered his complaints. A true conservative, he exhorted us to study arithmetic, music, geometry and astronomy as if they were one subject, thus

indicating that these studies had already distinguished themselves from each other by his time. Over the years, the cultures of the Mediterranean zone put less and less emphasis on the musical foundations of metaphysics. The fragmentation of the ancient cosmological unity continued to increase. Later, the Romans were less musically inclined than the Greeks or Egyptians, and understandably the monochord gradually lost its honored standing in the education system. Eventually, many of the keys to the old ways of thinking were lost or re-interpreted, since people no longer understood the deeper aspects of the underlying musical foundations.

In addition, various other 'number games' arose which confused the issue. Chief among these were numerology and gematria. These 'sciences' take numbers away from the temporal context of musical tuning into purely spacial frameworks which falsify harmonic realities. For example, what can it possibly mean that the 'essence' of the number 14 is a 1 + 4 = 5 "vibration?" In the strict, old scientific language of musical Harmonics, the essence of 14 is that it belongs to the 7-Limit family (i.e. it has prime factors 2 and 7). Gematria is even more arbitrary, simply assigning numbers to letters so that each word has a specific number value. Such musically spurious procedures were often mixed with legitimate Harmonics purposely (e.g. by Pythagorean writers such as Philolaus) in order to obscure the truth. Only if one had diligently done one's monochord 'homework' would he inderstand the real message of the lesson. Unfortunately, among most later writers, there is much numerology, and scant little harmonic substance. They either did not understand the underlying meanings of the numbers, or they had some understanding but were not divulging it. Indeed, secrecy became ever more popular in an increasingly authoritarian society.

Even though these new 'sciences' were based on the old musical symbolism, it was re-interpreted into abstraction. We also see this tendency in the emerging Qabbala and modern astrology. In addition, the new authoritarian religions were a major factor in both suppressing and re-working the old symbolism.

One of our best sources for tuning practices near the end of the ancient culture period was the Egyptian scientist Ptolemy (about 150 A.C.E.). By his time, the exploration of temperament was largely forgotten. Indeed, he re-interpreted Aristoxenus' parts as ratios. The old Arithmetic Mean on the monochord again reigned supreme. Ptolemy has left us a delightful assortment of JI scales, 3-Limit, 5-Limit, 7-Limit, 11-Limit, even one 23-Limit scale! The implication here is that ***any* just division is permissible.** Such emancipated thinking is definitely 'post Democritus.' The older tradition, championed by Pythagoras, Empedocles, and other conservatives, tended to be 5-Limit and/or 7-Limit. Ptolemy has transcended this limitation, suggesting complete freedom to the *n-Limit* in JI exploration.

The reason why I would describe Ptolemy's approach as 'post Democritus' is that the implied acceptance of n-Limit JI follows naturally from the temperament research of the previous generations. The n-Limit takes into account the peculiar complex relations between forms of JI and systems of temperament. First consider tempered systems.

Although relatively simple systems like 12-et form only a crude simulation of JI harmony, more complex 'resolved' systems like 53-et form increasingly good simulations of aspects of JI. These strange relations also work from the other side. The allowance of high prime-numbered ratios into sets of JI allows JI to simulate systems of temperament, even such relatively crude systems as 12-et. In other words, **given a certain degree of allowable complexity in either approach, similar results ensue.** Ptolemy's support for n-Limit JI shows that he had absorbed the 'materials' of the temperament approach, even though his presentation is, in many ways, a return to the old ways of Babylonian-Egyptian science.[9] Much of Hellenistic science has this characteristic.

It must not be forgotten that most musicians continued to tune the age-old JI scales, and not systems of temperament, which were probably always esoteric 'laboratory' constructions of interest to cosmological scientists. But by Ptolemy's time, musical tuning had largely de-coupled itself from many of the old magical and cosmological associations, although superficial remnants of these associations persisted. Indeed, they lingered on in various forms until the end of the 17th century.

Ptolemy's work points out a persistent feature in ancient (and Asian) tuning practices. These cultures are *pluralistic*; that is, they do not recognize *one* correct way of tuning the scale, but rather admit a large number of alternatives which are all equally valid. To use an ancient perspective, each tuning is a god in its own right, the only god which is (temporarily) actually existing, the other gods having been sacrificed. Nevertheless, all are equally valid expressions of the ONE high god. This pluralism is entirely consistent with the nature of JI, which allows a large variety of alternative scales. Such a 'polytheistic' attitude is still prevalent in many parts of the orient, e.g. in India, which largely preserved the ancient tuning practices and their attendant philosophies.

THE MEDIEVAL MONISM

What happened in the west? For various arcane theological reasons, the newly risen western branch of the Christian Church in Rome sanctioned *one scale only*--the 3-Limit Diatonic Ogdoad.[10] In other words, they supported a culture of tuning *monism*. The 5-Limit scales were ignored or suppressed as 'pagan.' The strict limitation of the line of fifths to eight tones bares this out. For the ninth tone would give an interval which is quasi-5-Limit (it is detuned by only a schisma, which can be practically ignored in the real world of actual tuning work). Hence the strict limit to eight tones. Obviously, there were also echoes of the ancient cosmic significance of the number eight. The evidence indicates that the new 'religion of the masses' attempted to destroy the ancient music culture just as much as they attempted to destroy the ancient temples. There was even a movement to suppress music altogether, an indication of how important music must have been to the pagans. Since this was impossible to achieve, they regulated its use and seriously re-worked its symbolism.

As their authority, they cited poor old Pythagoras, who had already long before become the object of various pagan religious cults. According to such writers as Boethius,

Pythagoras discovered and sanctioned 3-Limit harmony, and there is not even a mention of the *possibility* of the 5-Limit. Reading Boethius, one gets the impression that 5-Limit harmony was unknown, undiscovered, and never used. This ideological falsification of history is still believed by most orthodox western musicologists, who are intent on validating the myth of progress. They actually believe that there is no evidence for the use of 5-Limit tuning in the ancient world. Indeed, they believe that before Pythagoras no one knew that the 1:2 ratio is an octave! Presumably no one had ever touched the middle of a string and found the octave point.

The Christians were not the first people to re-make Pythagoras, but they were the most influential in the west. Historically, Pythagoras became the 'dump' for all things musical, and the other cosmologists were (and are) interpreted as if **musical issues are totally irrelevant**. Music was thus dethroned and marginalized. Even Pythagoras was henceforth assumed to know surprisingly little. For example, many modern scholars are still of the opinion that the *only* monochord division that Pythagoras knew was the division 6:12. Yet the overwhelming circumstantial evidence indicates that not only Pythagoras, but also the other cosmologists were virtuoso monochord explorers, who investigated ratios (both rational and irrational) to the limits of their intelligence.

Medieval Arabic tuners preserved the spirit of the old tuning approaches, although they also tended to theoretically replace the 5-Limit by the 3-Limit. We could say that Anaximenes' reforms had a long-term influence. Over time, the 5-Limit tunings were re-expressed as extended 3-Limit matrices. But while in the west it was restricted to the Diatonic expansion, in the Middle East and in Asia the long line of fifths preserved the Chromatic and Enharmonic intervals. For example, a tuning regime recorded in 9th Century Baghdad used a line of 17 fifths. In India they traditionally used 22. Such long lines of fifths assured the old 5-Limit intervals. Essentially, the aim was to create a large 'pool' of available tones from which they could generate an assorted variety of JI scales. Hence, in many parts of Asia, and Africa, the old pluralistic practices were maintained, even to this day.

European monism perhaps helps to explain the relative crudity of early European music culture, in comparison with the rich cultures of Turkey, Iran, and India. The European restriction to the 3-Limit Ogdoad, henceforth called 'Pythagorean,' held force from at least the time of Boethius (500 A.C.E.) until the 12th century.[11] Then there was a tentative extention of the line of fifths, so that by the end of the 14th century the original medieval eight-note keyboard was expanded to twelve per octave--the 'modern' keyboard. No doubt they observed the dreaded Ditonic Comma and stopped the expansion there.

Europe developed a very advanced music culture during the late 12th and 13th centuries, witnessed in the school of Notre Dame, Paris. There were strong Arabic influences on high medieval culture, especially in Spain, although the centre of medieval cultural activity was generally in northern France. Europeans went on the Crucades to conquer the Middle East, and returned with the instruments that we think of as typifying high medieval culture--the lute, rebec, recorder, and organistrum. Most medieval

ensembles were small, with instruments of contrasting colours, usually only one singer, and often a small drum. There is a certain 'rock-n-roll' element in medieval music which was typically middle-eastern in origin. Their main concern was with rhythmic development and complex melody and texture. Smooth vertical harmony was secondary, and much dissonance was tolerated. Such musical styles eminantly suit 3-Limit JI tuning.

By the end of the 14th century, with medieval cultural ideals in decline, southern France and northern Italy produced musical styles in which syncopation and other rhythmic complexities had reached unbelievable proportions not equalled until the 20th century. This was surely a fin-de-ciecle music culture ready for a radical shift. Indeed, this shift occurred at the beginning of the 15th century, the start of the musical renaissance in Europe.

THE RENAISSANCE-BAROQUE PLURALISM

The 15th century was one of the most important periods of western cultural history. During this time, a vocal model of harmony replaced the older medieval model, which, in spite of the motet, was always largely instrumental. The new style was characterized by a sweet harmony, consisting almost completely of simple major and minor triads prepared by discrete suspensions, to be sung by democratic ensembles of homogenious voices. Rhythmic complexities were toned down, since it was now harmony which was of central interest. This style matured during the century. By the end of the 15th century, we see in such transcendant music masters as Ockeghem and Josquin, the birth of what we now call the modern *common practice* period. This term generally refers to the use of tonal, key-centred chordal harmony in progressions based on dominant relations, etc. During this period we also see the emergence of the modern notation of sharps and flats. To a large extent, the rest of European musical history (until this century) was the progressive working out of the implications of this particular harmonic paradigm.

We witness the early manifestations of this new harmonious style at the beginning of the 15th century in the English composers Leonel Power and his younger contemporary John Dunstable, who was an astronomer-mathematician as well as musician. Here is the most significant 'British music invasion' in history (before the Beatles!). The continental composers of the generation of Dufay eagerly embraced the new style, which the theorist Tinctoris described as the 'English sweetness.' The 15th century was the period of European history when the 5-Limit Diatonic paradigm definitely gained ascendancy over the old 3-Limit paradigm. The 4:5 mediant was finally accepted throughout Europe as a consonance in the musical *practice*, even if it was still not accepted among all theorists. Historically, theorists have almost always lagged behind actual practice.

We would naturally think that the 15th and 16th century choral music is a reservoir ideally suited to 5-Limit JI. *Yet this is definitely not the case,* although many choirs must have (and still do) approach pure just intonation in their practice. But when we examine the scores of this period, we see many instances in which the composer writes a progression involving 'illegal' comma juxtapositions. The classic, most common example

is where one goes into the progression holding the comma-lowered form of the supertonic (\D), but the harmony around you then changes in such a way that one should now be singing the D. A composer who is intelligently working in pure 5-Limit JI must develop some sensitivity to comma-shifts, thereby avoiding certain chord progressions that display these juxtapositions.

Yet these very progressions had become the favourites of the renaissance composers! For this, and various other reasons, I must conclude that the new tuning paradigm was necessarily a *temperament*--specifically, the 'common' meantone temperament associated with 31-et.

Meantone tuning was not 'officially' acknowledged and defined by a theorist until early in the 16th century (Pietro Aron, 1523, Venice). Yet there is much circumstantial evidence that meantone was a paradigm for the musical *practice* also in the 15th century. In order to understand why, we must briefly consider the harmonic architecture of the classic meantone tuning, a line of fifths from Eb to G#. In this system, there are eight good major triads (on Eb, Bb, F, C, G, D, A, and E), three septimal major triads which are quite dissonant and not usable (on B, F#, and C#) and an extremely dissonant 'wolf' major and minor triad on G#. Looking at the other minor triads, there are eight good minor triads (on C#, F#, B, E, A, D, G, and C), and three sub-minor, septimal triads (on F, Bb, and Eb) which are beautifully 'dark' and quite usable. This is the triad inventory of the classic meantone tuning.

When we examine the renaissance practice, we see a **consistent avoidance of the bad triads** in the literature. They used only the good triads (which are much more like 5-Limit JI triads in sound than like 3-Limit triads). Thus the musical syntax suited meantone tuning. I have examined many scores over the years, and it is extremely rare to find an exception to this rule, right through until the mid 16th century. The period from the beginning of the 15th to the middle of the 16th century conforms very closely to the 'restrictive' aspects of the classic meantone tuning.

From the middle of the 16th century, among the madrigal composers, we see the 'expansive' aspect of meantone tuning coming to the fore. For meantone tuning does not lend itself to an artificial restriction to twelve notes per octave. Rather, on a practical level, it forms a line of thirty-one fifths. The madrigal composers, beginning with Cipriano de Rore, expanded the line of fifths beyond twelve, beginning naturally enough with the inclusion of Ab as well as G#. The notation of sharps and flats became necessary and was a direct result of meantone *practice*. It was also during this time that keyboards with 'split' keys began to be built, in order to accommodate more of the potential of the system. The culmination of such efforts was Vicentino's 31-tone keyboard from 1550. This keyboard and its virtuoso player Luzzaschi must have inspired Gesualdo to compose his ultra-chromatic 'avant-garde' meantone harmony by the end of the century.

The development of keyboards as an aid to vocal composition was a significant factor in the shift to meantone temperament. According to various traditions, the

harpsichord (and to a much lesser extent, the clavichord and organ) had *always* been tuned meantone. The origins of the harpsichord have been traced back to the 'echiquer' in 14th century Britain.

My suspicions of the British roots of the renaissance tuning are also fueled by other factors. First of all, there as a well developed choral traditon, especially in Wales. Even during the 13th century, the islands were noted for treasuring a richer harmonic sonority than the continent. In addition, we see the practice of singing in parallel thirds, which became the 14th century English Descant. This practice consisted of singing all first inversion triads--a style suited to meantone tuning. Moreover, it was an English monk, Walter Odington (c. 1300) who first justified ratios of 5 as consonances. Meantone tuning favours these ratios. These factors lead me to conclude that meantone tuning arose somewhere in the regional music of the islands during the 14th century. Then it spread to the continent, which was then ready for it, in the time of Dunstable.

There is also the possibility that esoteric music circles in Britain kept alive the ancient meantone tuning, which was the secret golden-section related tuning of the Pythagorean brotherhood. There exist various oblique references to meantone tuning in the writings of the Pythagorean philosophers Archytas and Plato. The ancient Greeks knew of it, and it may have escaped the repression and survived in Britain and elsewhere. Of course, this is pure speculation, but it is a historical fact that the meantone tuning had a stronger hold on Britain for a longer time than any other European country. Speculation aside, during the 15th century the practice became widespread.

This is not to say that everyone now tuned meantone. It was mostly keyboards and their attendant choirs that did so. We all know that the classic meantone tuning, with all its restrictions, is much more singable than is the old 3-Limit (Pythagorean) harmony. On the other hand, fretted instruments such as lutes, viols, etc., were usually (but not always) fretted for systems approaching 12-et or Pythagorean (the differences between them are not so great for the diatonic scale). Such conditions led to the development of consorts of instruments, rather than a full symphony traditon. Various instruments did not belong together due to intonational conflicts.

Starting in the 15th century, **European music culture again became pluralistic**, and tolerant to tuning alternatives. Again, as in ancient Greece, there ensued a lively debate and controversy around the subject of musical tuning. Different regions of Europe evolved different practices, as can be seen in the construction of wind instuments. There was no standard pitch. Matters of musical tuning were freely explored without the medieval, theological restrictions, although, as usual, many theorists remained strictly conservative. Yet the 16th century also produced such progressive theorists as Salinas and Zarlino, and the 17th century Mersenne and others.

However, there was a big shift of emphasis between this renaissance-baroque pluralism and that of Asia and the ancient cultures. **The ancients sought mostly varieties**

of Just Intonations, but the renaissance-baroque tuners sought mostly varieties of temperaments.

The most significant reason for this growing dominance of temperament was the rising importance of keyboards and fixed fret instruments in an atmosphere where modulation held increasing interest. During this time, instrumental and regional musical styles rapidly evolved. This evolution ironically led to the eventual demise of meantone temperament itself in favour of irregular (well) temperaments and eventually 12-et. Although efforts were made to develop suitable instruments, no one came up with a workable keyboard that had all 31 notes, or even half of them, in a playable and affordable format. Eventually, when the more distant modulations were more and more in fashion, practical musicians opted for inferior tuning systems because they better suited the old 'time-honored' medieval keyboard design. In other words, **technological expediancy won out over intonational accuracy.**

Nevertheless, it must be stressed that the ideal of 5-Limit vocal JI underlies the renaissance shift to meantone temperament. As long as one sticks to the 'good' triads, it is much more like JI than is the old Pythagorean tuning (or 12-et). They wanted JI, but meantone was close enough for the practice. When they sang without the instrumental accompaniment, they must have sub-consciously shifted their intonation toward just, a subtle shift from meantone temperament. Modern choirs, although trained to think that 12-et is 'correct,' also shift toward JI.

The movement toward forms of well-temperament and eventually 12-et appears to have formed in the second half of the 17th century in parts of Germany. These ways of tuning are best seen as a compromise between meantone tuning and Pythagorean. Here is a likely scenario for its discovery. A tuner starts with the classic meantone tuning, and then makes various adjustments in order to get rid of the wolf triad, thus making all twelve keys possible. He does this by tuning his fifths on the 'black' keys pure rather than tempered. In doing so, he finds that the triads in different keys have subtlely different 'colours' or sound qualities. Once he has decided that this is to his liking, he has shifted to the Baroque tuning attitude.

The well temperament ideal comes out of the artificial but entrenched restriction to twelve notes per octave. The polarity between the 5-Limit and 3-Limit diatonic pattern is distributed between the chromatic scale, so that the triads in the 'common' keys (e.g. C) are closer to meantone in sound; that is, the thirds are better and the fifths more tempered, while the triads of the 'distant' keys (e.g. Db) are close to the 3-Limit ideal; that is, with sharper thirds and purer fifths. The shift from the common to distant keys is made orderly and gradual. In order to do this, none of the thirds are absolutely pure (as in meantone), and the fifths have varying amounts of temperament. This gives the beautiful effect that each key has its own character in modulation.

This movement was greatly assisted by the invention of logarithms in the 17th century. Using this tool, the most complex and subtle temperaments could be laid out on a

monochord. These new systems were seen as more progressive and 'scientific' than the old meantone tuning. Using the schisma as a sensible 'atomic' unit of temperament, such tuner-theorists as Neidhardt, Marpurg, and Werckmeister explored this new territory. The highest refinement of this very evolved temperament ideal was achieved by Thomas Young's temperament #2, published in 1801. However, by this time, the era of well-temperaments was drawing to a close.

In spite of the heady atmosphere of pluralism, we must not under-estimate the benign hold of meantone temperament over the European psyche right from the 15 century until the end of the 18th century--much longer than the period in which 12-et has been the dominant ideal (since the early 19th century). Indeed, some organs in Britain were still tuned meantone in the middle of the 19th century. **It was the meantone temperament which put European music culture on its own unique path.** But without the use of all 31 keys, the system had modulatory limitations. By the 18th century, with rapid 'flashy' modulations to distant keys becoming the rage, it was regarded as old fashioned. Well-temperaments were so much more practical. Without a suitable keyboard design, meantone tuning was doomed.

During the height of the meantone era in the 17th century, we saw Mersenne attributing consonance to ratios of the 7-Limit. This development was quite natural, since practical musicians had already become accustomed to septimal intervals through the meantone practice. Remember that the classic meantone tuning (from Eb to G#) has three sub-minor triads that well simulate a 6:7 ratio. Also, the 'dominant seventh' chords on Eb (i.e. Eb G Bb C#) and Bb (i.e. Bb D F G#) well simulate the Harmonic Series seventh chord with its 4:7 ratio. These chords, with their unique sonority, were named the 'German seventh chord' when used in the function of the sub-mediant. Here is another example of a theorist catching up to the practice.

18th century baroque theorists, notably Rameau, used Mersenne's exploration of the Harmonic Series as support for just ratios as the source of consonance. But these same theorists were also quite happy to recommend a variety of temperaments for the actual *practice* of music. This gap between theory and practice began in the renaissance between JI and meantone, then widened further with the use of well-temperaments and equal-temperament. The cause was the technological difficulty in implimenting the fashionable musical styles on a workable keyboard.

In spite of these problems, European culture was happily pluralistic until the end of the 18th century. It was during this great **meantone era** that the European musical ideal fully separated itself from the mainstream of world tuning culture. Europe evolved its unique instruments and musical styles. During this period we also see the highest positive progressive evolution of the European music culture.

THE INDUSTRIAL MONISM

This situation was to radically shift during the 19th century, leading to the collapse of the formative ideals and the slow degeneration of the European music culture. Now, at the end of the 20th century, we are in the midst of extricating ourselves from the philosophies and practices set in motion during the last century.

The 19th century saw serious social and environmental affects resulting from the industrial revolution. The most important aspect for us involves the vast amount of machine *noise* that was introduced into the environment. As a response, orchestras were made larger and louder, wind instruments were re-designed and invented to be louder, and the piano was re-designed with a metal frame in order to crank up string tension and make a bigger sound. With all of these developments came a new emphasis on industrially inspired standardization--standard pitch and standard tuning. The new piano was more difficult to tune; hence, a professional class of piano-tuners evolved. Naturally, in 'scientific' fashion, they decided that 12-et was the best standard system.

By about 1810 the equal-temperament was becoming the dominant ideal in Europe. The piano had become the king of instruments, the darling of composers and performers, and equal temperament was its tuning. The other instruments followed suit. However, it is not easy to accurately tune 12-et on keyboards, before the days of electronic devices. Consequently, most tuners *thought* that they were tuning equal when, in reality, they were tuning 'shallow' forms of well-temperament in which there were still vestiges of key-coloration. It must be remembered that, in a well-temperament, the amount of contrast between the common and distant keys can be controlled. As the century progressed, the contrast became more and more reduced, so that the difference between these temperaments and equal-temperament eventually dissappeared. When this happened is difficult to say, but it was late in the century.[12] The rigorously high standards of modern piano tuning did not commence until certain technical discoveries were made, after 1917.

In some respects, the growing dominance of the equal-temperament reflects a ressurgance of the old medieval attitudes, only **now the monism centred around 12-et rather than the Pythagorean scale.** The results were quite deleterious for the music culture. The old, carefully evolved tonal system, which came from the meantone era, was largely undermined. The reasons for this deterioration stem from the inherent architectural weaknesses of the 12-et system itself; namely, the 'special' ambiguous tritone, and the over-abundance of symmetrical harmonies. As a consequence, the system is better suited for 'atonality' (functional confusion?), whereas the extended meantone system is better suited to a subtle extended tonal modality. Moreover, in 12-et, all the colour differences between the keys are eliminated, so that modulation itself is cheapened.

Not everyone went down the 12-et path during the 19th century. New and profound developments were made in acoustics, especially by Hermann Helmholtz. For the first time in history, instruments more accurate than monochords were available for

measuring interval relations. For various reasons, the monochord itself was only accurate to roughly a quarter of a comma, further refinement accomplished by ear. New scientific developments underpinned JI as the true basis for harmony. Consequently, Helmholtz and others championed JI (and its tempered simulation in 53-et). Following his lead, several new keyboard designs were developed, mostly in Britain. The best of these new designs was by H. M. S. Bosanquet (1876). In fact, his design (with minor modifications) is perfectly suited to 12-et, 19-et, and 31-et, which are all meantone-related temperaments. However, ironically, he intended it for 53-et, a system for which it is not so well suited, since the fingerings of the consonant chords are much more awkward. Hence the old problem remained--no adequate keyboard for JI.

Also, the design came tragically too late for the meantone system, which most theorists now treated as a defective historical curiosity in the upward evolution toward the one, 'correct' 12-et system. This notion, still widely believed, is quite absurd. First of all, it is innappropriate to apply the model of progress to cultural norms, which do not follow a 'straight-line' development. Cultural ideas are found, lost, and re-discovered. But more important than this, the notion that 12-et is musically superior to the older systems is just not true. It is only more expediant, that is all. An impartial examination of the historical development in the west shows more a 'devolution' than an evolution. First we have unrestricted n-Limit JI in Ptolemy. Then we have a very restricted version of JI in the medieval system. With the renaissance we see the move to a superior system of temperament (extended meantone or 31-et). Then, mediated by the well-temperaments, the meantone approach is abandoned for a cruder system of temperament (12-et). Is this progress? It appears to me that **the highest development of tuning alternatives in this scenario was the work of Ptolemy.** The modern superficiality of the harmony system bares this out. Moreover, cultures that maintained the old JI norms, as in India, preserved the exquisite microtonal subtlety which must have been present in the ancient 'western' cultures. Although the renaissance shift to extended meantone was conducive to wonderful harmonic developments, its abandonment for 12-et has resulted in harmonic trivialization and disintegration.

The revisionist view of the illustrious meantone system, which lay at the heart of the high renaissance-baroque music culture, is still being taught. The system is seen as defective, partly because it requires more notes to the octave than twelve, yet there *must* be only twelve notes to the octave (the influence of astrology?). Moreover, many scholars who make such judgements are largely unfamiliar with the architecture of the system itself, and have not properly compared the system with 12-et. This is indicative of the general lowering of intellectual and experiential standards since the 19th century. We can see this in various 'myths' which are still believed by many. For example, there is the erroneous story that Bach invented and used equal-temperament, and the general confusion of well-temperaments with equal-temperament. Then there is the further rising of Pythagoras' star, since scholars want to believe that all science and high culture began in Greece (Europe) and not in Asia and Africa. Finally, there is the under-valuation of the importance of tuning itself; consequently, most modern scholars still believe that there is no causal influence between tuning and musical syntax.

If meantone tuning was unjustly maligned during the 19th century (and now), the situation was even worse for JI and 53-et. It was now considered impractical, useless, even impossible! This, in spite of the fact that most high music cultures had *always* been using, and are still using, varieties of JI. But the 19th century proponants of JI had remade the image of JI music to mirror the current temperament-influenced styles. They wanted Richard Wagner's tritone-rich chord progressions, only tuned pure. There was little contact with the ancient high music cultures of Turkey, Egypt, India, or China, which had developed the perfect musical instruments and languages for JI in their long histories. In the 19th century social climate of growing racism and colonialism, the music cultures of Asia and Africa were demeaned as 'exotic' and 'primitive.' These attitudes were perpetuated in the 20th century until quite recently. Consequently, in the west, JI itself became a sort of exotic plant, or curiosity. Even though it has been the mainstream of world music culture, and it is underpinned by the only valid theory of acoustics available, it has become largely a side-show in modern western music culture.

PLURALISM RESSURGENT

The situation is now changing in positive ways. The breakdown of colonialism and the rise in communications has made foreign musical languages less remote, less strange. Many musicians, fed up with the sterility of the western system, have rediscovered the rich musical languages of the orient as a source of nourishment. On the American scene, the seminal composer-theorist-instrument builder Harry Partch was consciously influenced by Chinese musical culture as well as by Ptolemy. We are moving toward a world music culture.

In addition, new technologies have broken down many barriers. Recordings and concerts have made alternative musical languages more familiar to us. Also, electronic media, such as synthesizers and computers, are well-suited to exploring tuning alternatives. One does not even need a 'good ear' to delve into the world of musical ratios. At the same time, there is much more knowledge and awareness now about the architecture of harmony in general. In such an environment, a healthy shift toward pluralism is inevitable and is certainly now happening.

Although attitudes are changing, there still exists the prevalent notion that the Asian musical languages are somehow 'static' as opposed to our cultural history which is 'evolutionary.' These languages may appear static because they reached a high level of evolution a long time ago. They embody complex continuities. By contrast, western developments occurred rapidly (in the space of a few hundred years), but are now in danger of reaching a dead end. We should recognize that what happened in the west was but a temporary historical diversion from the mainstream of world music culture. We now have the opportunity to re-integrate with that mainstream.

The way forward for the west is to initiate a dialogue with the traditional approaches, for our own mutual benefit. Indeed, this is now happening. Such a dialogue

can foster new musical languages which incorporate the best of the western experience into the mainstream. In such emergent languages, varieties of JI are likely to play a leading role, just as they did in the past. In spite of the present prevalence of 12-et, the future looks bright for JI.

NOTES:

1. This paper is dedicated to professor Ernest G. McClain, who introduced me to the notion of pluralism-monism, as well as a host of other valuable insights. Special thanks are also owed to Mark Rankin and John H. Chalmers, for useful criticisms and valuable suggestions. However, these people are not to be held responsible for my peculiarly heterodox view of history.

2. I have attempted to keep technical information and references to sources to a minimum in this paper, in order to improve its readability for a general public. Such information is thus relegated mainly to these end-notes. Most people curious about musical tuning have only a small familiarity with alternative approaches, perhaps even less with monochords, and the associated archaic arithmetic. If this describes you, take heart, you can hopefully still follow the gist of my argument. For those people who fear that they have *no* familiarity with fundamental concepts, here is a short introduction to the territory:

A **harmony** is a pattern of relatedness between vibratory events (musical pitches). Such patterns are defined or accurately expressed by using number **ratios**, which interact with one another by the process of multiplication-division. A **JI** harmony uses only whole-numbered ratios, which can ultimately be derived from the **Harmonic Series**. On the other hand, a **tempered** harmony uses irrational ratios which can never be accurately expressed through whole numbers. We hear such tempered ratios as mistunings or 'temperings' of the Harmonic Series **Norms**. The term 'et' (for example 12-et) stands for the division of the octave into an equal-step scale of irrational ratios (in this case twelve to the octave).

The laws of **Harmonics** (ancient Canonics or the tuning sciences) can be largely derived from two ultimate sources, one provided from nature, the other from arithmetic. The first source is the fact that the Harmonic Series is not symmetical. From this reality arises issues of reciprocal relations, complimentarity, symmetry etc. Such issues are largely side-stepped in this paper, even though they had a profound effect on deeper aspects of ancient metaphysics. The second source is the **First law of arithmetic**. It states that any number can be uniquely expressed as the product of prime factors. Numbers, in the context of musical tuning, take on 'family relations' through their prime factors. Consequently, a JI harmony can be described as 3-Limit, 5-Limit, 7-Limit, and so on. A **3-Limit harmony** uses ratios which are derived from the prime numbers 2 and 3 alone. Higher primes are excluded.Thus, for example, the ratio 16:27 is 3-Limit,, because $16 = 2^4$ and $27 = 3^3$. A **5-Limit harmony** uses the primes 2, 3, and 5, the source of many an ancient trinity. These numbers are often called Regular Numbers or Babylonian Numbers. A **7-Limit harmony** uses the primes 2, 3, 5, and 7. Thus the sequence progresses up the series of prime numbers (the Roots of harmony) 2, 3, 5, 7, 11, 13... Each new 'level' contains all of the previous levels as a subset. However, each additional 'layer' introduces a quantum leap in complexity and field saturation--a new 'dimension' in the ancient

symbolism. Consequently, 5-Limit harmony has always been the mainstream of JI tuning culture. The 11-Limit and beyond have always been rather esoteric, almost alien territory. In the context of musical tuning, simple numbers have elevated status in comparision to complex numbers with their 'exotic' prime componants.

3. Professor McClain's books are available through the Just Intonation Network.

4. It is worthwhile here to mention the monochord divisions which have the greatest cosmological associations, although the reasons for choosing these over the available alternatives are too convoluted to pursue in this essay. Thus, in a rather dogmatic fashion I will simply state that the most important divisions are the 5-Limit monochords 30:60, 72:144, and 360:720. These very same divisions form the core of McClain's research. Closely associated with these divisions are the 5-Limit sequences 60:120, 36:72, 24:48, and 180:360. You may notice that all of these divisions have close harmonic relations to each other. Among the important 3-Limit divisions, priority goes to 6:12, 18:36, 72:144, 96:192, 576:1152, and 1152:2304. Of course, the elemental divisions 1:2, 2:4, 3:6, and 4:8 have over-riding metaphysical importance.

5. Actually, the symbolic meaning of Aether as an Element and its relation to Air and Fire is rather complex and shifting in the ancient world. In some circles it later stood for the ONE, a natural evolution from its old association with the Element Fire. There is also evidence that, in the Greek world at the time of Empedocles, Aether had meanings related to Air. See the excellant book: ANCIENT PHILOSOPHY, MYSTERY, AND MAGIC--Empedocles and the Pythagorean Tradition, by Peter Kingsley (Clarendon Press Oxford), 1995.

6. The relation between setting a musical tuning and establishing a calendar are conceptually very close. Both involve temporal procedures in which one measures periodically vibrating phenomena. The only difference is a matter of scale. Music deals with very fast periodic vibrations (hundreds per second), whereas the calendar deals with the slow and stately periodic cycles of the sun, moon, and planets. However, the relations between these cycles can accurately be described as intervallic. Ancient cultures tried to make the naturally 'messy' or complex calendrical numbers conform to the simpler monochord numbers. For the convoluted relations between these two branches of ancient science, see my paper: HARMONICS IN ANCIENT CALENDRICS, unpublished, available on request.

7. The 5-Limit monochord 72:144 is the furthest extension of the 'double-strand' on the triangular matrix before the encounter with an 'illegal' comma juxtaposition. Thus it is the 'full' (to use Plato's description) Diatonic harmony, a symmetrical structure embodying the two usual diatonic heptad harmony subsets, which are not symmetrical. It is much more consonant than its 3-Limit 'cousin,' the division 1152:2304, the division given by Euclid and Boethius and supposedly discovered by Pythagoras. The full sequence is: 72:80:90:96:108:120:128:135:144 (i.e. C Bb Ab G F Eb D Db C). This division puts the Diatonic Ogdoad into its smallest possible integers; hence, it has priority over other

'modes' of the Ogdoad on the monochord. These numbers were applied to the distances between the celestial bodies. The most usual (but not the only) order was: Earth, Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn, Stars. The ancient assignment of a monochord to the planets is a complex subject. Most of the information comes from very late sources who appear to know very little about monochord arithmetic. There was also a definite historical shift which I am ignoring here in the interests of brevity. (In summary, this shift involved the increasing tendancy to see the One as male, and also the displacement of the goddess from the middle, to be replaced by the Element Fire). After investigating the clues left by Plato, Aristotle, Euclid, Nicomachus, Pliny the Elder, Martianus, Censorinus, Theon of Smyrna, Achilles Tatios, Cicero, Dio Cassius, Plutarch, and Ptolemy, I came to the conclusion that most of the 'implied' alternatives are closely related, i.e., divisions 18:36, 36:72, and 72:144 among the 5-Limit. Very few sources give the numbers directly, for whatever reason, and often the descriptions are so vague that they could be equally well interpreted as the 3-Limit version of the same harmonies, especially division 1152:2304 and its parents. However, the 5-Limit version is the most consonant and the most likely original. The detective work involved is properly the subject of another essay.

8. Many scholars believe that only rational (just) ratios are possible on a monochord, but this is simply not true. Irrational ratios can easily be calibrated by using a geometrical method associated with the *Geometric Mean*. However, I would conjecture that such procedures were quite esoteric, like the use of this Mean in Plato. Amazingly enough, the geometrical construction that allows irrational ratios on a 'line' was attributed to Thales, the very *earliest* of the Greek cosmologists. This is one more of the many reasons why I have concluded that the confrontation with the irrational lies behind the cosmological 'reforms' of the early Greek scientists. For more on the method for setting tempered ratios on a monochord, see my paper: ARISTOXENUS AND EQUAL TEMPERAMENT: A RE-APPRAISAL, which is unpublished but available on request.

9. Actually, there are some differences. Rather than expressing a division in its smallest whole number terms (the ancient method), he uses a standard monochord division (60:120--itself an important ancient division). Then he gives the inevitable fractions in sexagesimals--another tribute to Babylonian science.

10. The early Christian version of 'the' scale is simply the 3-Limit version of the old 5-Limit cosmic monochord 72:144. The numbers for the division 1152:2304 are the following: (compare these pitches with those for the old cosmic 72:144 scale given above in Note #7) 1152:1296:1458:1536:1728:1944:2048:2187:2304 (i.e. C \Bb \Ab G F \Eb D \Db C). It is natural to consider 'C' as 'doh' or the tonic or mese, if we want a function-based notation which takes into account the comma-shift. But the early Christian writers, following Boethius, substituted 'lah' or pitch 'A' as their mese. (The application of the Roman alphabet to the pitch scale was one of the major historical achievements of the early Christian period, although it was not explicitly stated until the time of Odo of Cluny). Hence they notated the above scale using 'A' as mese, thus giving the series of pitches A G F E D C B Bb A. This notation became the standard notation of the middle ages. The

eight-note medieval keyboard with its one raised key was designed for it. Observe that this notation crudely eliminates any use or even awareness of the functional comma-shift. **The import was to deny the validity or even the existence of the 5-Limit alternative.**

11. Of course, this is an over-simplification in the interest of brevity. For an example of the purported use of microtones in the Gregorian Chant, see: EVIDENCE FOR THE TRADITIONAL VIEW OF THE TRANSMISSION OF GREGORIAN CHANT, by David G. Hughes, from the Journal of the American Musicological Society, Vol. XL, No.3, (1987). For a novel method of erecting a 3-Limit Diatonic Ogdoad scale on the monochord, see the Enchiridion Musices by Odo of Cluny (ca.935), in SOURCE READINGS IN MUSIC HISTORY, annotated by Oliver Strunk, Vol. 1, 1950.

12. These shallow well-temperaments can be called Victorian Temperaments. See the highly informative book by Owen H. Jorgensen: TUNING: containing THE PERFECTION OF EIGHTEENTH-CENTURY TEMPERAMENT, THE LOST ART OF NINTEENTH-CENTURY TEMPERAMENT, AND THE SCIENCE OF EQUAL-TEMPERAMENT; Michigan State University Press, East Lansing, 1991.