A COMPARISON OF THE MUSICAL AND SCIENTIFIC THINKING OF XENAKIS WITH THAT OF ANCIENT CHINA: THE ARCHITECTURE OF SCALES AND THE NOTION OF LÜ.

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ABSTRACT

Many consider Xenakis' most important contribution to music to be his invention of stochastic music and sieve theory. This music philosophy has many parallels with ancient Chinese musical thinking despite obviously different sonic outcomes. This paper examines one particular aspect of his stochastic and sieve theories: the creation of scales in relation to the ancient Chinese notion of lü, or scale temperament.

With his theories rooted in ancient Greek and Byzantine music, Xenakis differentiated between the "outside-time, in-time and temporal" musical architectures of scales and modes. He aimed to demonstrate "their abstract logical construction" and to express "in a simple but universal mathematical and logical language what was and what might be valid in time (transverse musicology) and in space (comparative musicology)" [8: 182-3]. A comparison with Chinese lü validates his claim in a uniquely different culture, illuminating essential qualities in Chinese music such as multiple temperament, an outcome which results from simultaneously embracing the three types of musical architecture. The discussion also examines related ambiguities surrounding the concepts of chance and determinism, and the boundaries of Chinese musical scales, and considers the limitations of human constructs over aural empirical experience and intuition.

1. INTRODUCTION: THEORIES DERIVED FROM A MUSICAL COSMOLOGY

Xenakis and the musical theorists of ancient China shared a profound belief that music should essentially reflect an understanding of the nature of the universe. In the court society of ancient China this meant that music assumed a critically important formal role in establishing standards and metrics that helped, for example, to regulate the calendar and to maintain social harmony. For Xenakis this belief has helped to create a unique and visionary musical language that intimately engages with the scientific thinking of our own time, whilst recognising a debt to western traditions by drilling into the bedrock of ancient Greek philosophy and science.

By examining parallels and differences between these comparable musical-scientific contexts, it is possible to gain unique insights into both. Xenakis might have appreciated a metaphor from contemporary cosmology: a conceptual *Einstein-Rosen Bridge*, or *Wormhole*, between two ostensibly alien cultural universes that facilitates free movement of thought-traffic and an escape from the exigencies imposed by local ideological gravity.

Xenakis himself aspired to a state independent of time and space, regretting that he was "born too late – I had missed two millennia." [6: 15] whilst also celebrating the music of non-western cultures, knowledge of which can help challenge contemporary assumptions and re-invent lost values: "Tonal music ... serial music ... Indian music … Japanese music, and so on … They are all separate worlds, continents or islands, each with its own closed rules. One has to examine what these islands have in common, what mental structure is present deep down in all of them; whether there is a path leading to each and whether it's possible to create a higher order." [6: 51].

Amongst the many stimulating links between the musical thinking of Xenakis and ancient China, this paper will focus particularly on issues relating to tuning and the structure of scales, or ordered note sets, representing the fundamental materials out of which musical structures may be created.

2. OUTSIDE-TIME, IN-TIME AND TEMPORAL MUSICAL OBJECTS

In his earlier writings (later modified) Xenakis differentiated between "outside-time", "in-time" and "temporal" organisation of musical architectures such as scales and modes [6: 183]. *Outside-time* musical objects are logically ordered note sets that do not contain any sequential implications. They exist as temporally independent constructs, derived from a formal mathematical process used to create a pallet or disconnected note vocabulary. *In-time* musical objects are ordered sequentially to provide contingent musical material that suggests linear motion, progression and resolution. *Temporal* musical objects exist in specific moments of time.

Not only does this system of classification offer specific insight into Xenakis' thinking, but it also maps well on to the contexts of Chinese musical theory to provide a helpful framework for comparative discussion. This is summarised in Table 1.

	Outside-time	In-time	Temporal
Xenakis' Theory	Sieves Chromatic scale Stochastic music	Diatonic scale Modes Serial music	Sound event The moment
Chinese Theory	12 Lü as benchmark standard Sets of bells	12 Lü derived from Qin tuning Pentatonic Modes	Root pitch (*huang zhong*) 12 Lü anchored to the calendar and seasons (astronomical measurements)

Table 1: Parallels in Chinese and Xenakis' classification of musical objects

Although this arrangement possesses an attractive logic, in practice variations in the precise functions and origins of objects, techniques and materials complicates attempts at straightforward categorisation.

3. XENAKIS' CLASSIFICATION APPLIED TO WESTERN MUSICAL OBJECTS

3.1 Outside-time: Sieves and stochastic music

Chief amongst Xenakis' arsenal of outside-time architectures are his Sieve theory and stochastic techniques. A sieve is essentially a generalisation of a musical scale, defined algebraically by superimposing a group of logical filters onto a proto-set of simply ordered objects. The resulting set of sieved objects, typically note pitches, possess a mathematical relationship but do not contain within themselves any suggestion of sequential ordering. They constitute a time-neutral resource for a composer operating within a formal framework. Simple examples include chromatic and octatonic scales. Whilst recognising historical antecedents, particularly amongst the theorists of ancient Greece, Xenakis made bold claims for sieve theory, as a revolutionary method capable of encompassing "all the scales used, both in the past and in other cultures, as well as the ordered sets of the future" [6: 96].

Stochastic techniques provided Xenakis with the tools to manipulate his musical materials according to theories of probability and so escape the deterministic (in-time) restrictions that he so despised in conventional music theory and composition. In doing so Xenakis drew on recent scientific models to produce a music, and accompanying theory, which intrinsically and uniquely provided an audible representation, or idealisation of the nature of the universe as currently understood [6: 76].

It could be argued that Xenakis gave his outside-time structures an almost sacred status, as a repository of 'higher' knowledge possessed of uniquely relevant authority; a contemporary rational equivalent to an ancient imperial standard.

3.2 In-time: Scales. modes and series

By way of contrast conventional scales and modes contain implied movement, including notes which are expected to resolve on to other notes, and notes which function as a 'root' from which a melodic line moves and to which it then returns. Xenakis considered these in-time phenomena hugely restrictive, dismissing the accompanying European traditions of polyphony as "a highly original invention of the barbarous and uncultivated Occident" [8: 191] Elaborating in the context of his 'grand theme', he suggests: "This degradation of the outside-time structures of music since late medieval times is perhaps the most characteristic fact about the evolution of western European music, and it has led to an unparalleled excrescence of temporal and in-time structures. In this lies its originality and its contribution to the universal culture. But herein also lies its impoverishment, its loss of vitality, and also an apparent risk of reaching an impasse. For as it has thus far developed, European music is ill-suited to providing the world with a field of expression on a planetary scale, as a universality, and risks isolating and severing itself from historical necessities." [8: 193-4]

Xenakis was particularly disparaging in his criticism of atonal serial music, which exercised a debilitating hegemony at the time he was developing his theories. It had "practically abandoned all

outside-time structure … endorsed by the dogmatic suppression of the Viennese school, who accepted only the ultimate total time ordering of the tempered chromatic scale" [8: 193].

3.3 Temporal: Actual occurrence

Xenakis did not elaborate on his third category, which he explained as the actual occurrence of an event. Indeed, it was subsequently dropped as a separate conceptual category. But, as elaborated below, it is a concept particularly relevant for Chinese musical theory, which was sensitive to particular moments in time defined in interlocking cycles of hours, days, months, years and epochs. There are, however, equivalents in western traditions in the temporally anchored music of acoustic signals such as church bells and clock chimes, and in musical traditions associated with seasonal social and sacred rites.

3.4 Doubts and ambiguities

Two issues in the development of Xenakis' thinking have interesting parallels in Chinese musical theory and its cultural context, and are worth more detailed comment.

First, there is the implication that "outside-time" architectures provide the theoretical foundational resource from which "in-time" materials such as modes may be generated or assembled, implying dependence of the latter on the former; or intellectual supremacy of a theoretical system conceived as "bypassing evolution" [6: 96] over empirical experience. The development of both western and Chinese musical theory (see 4.2 and 4.4 below) suggests that directional "in-time" modes, the ear and intuition, establish the ground from which the theoretical ideal is abstracted. To work backwards to recover the same object (i.e. mode or scale) but defined in an alien language restricted to the terms of reference of the abstracted axiomatic system, risks compromising the potency of the original object, which may contain implicit relationships or qualities the axiomatic system is not able to recognise. That is not to question the validity of the abstracted axiomatic system itself, which may uniquely recover or extrapolate matters of fundamental structural significance that conventional or alternative theories may have missed or suppressed, and so form a powerfully original theoretical and compositional resource.

Second, in discussing the historical context of chance, Xenakis is surprisingly dismissive of the Chinese *I Ching* (*Yi-jing*) as mere superstition, a "mysterious web of signs, sent by the divinities" [8: 204]. Though otherwise accepted as a genuine example of chance fulfilling a significant role in culture, eager to distance himself from John Cage, it seems that Xenakis allowed himself to be misled by the illusion that its adherents use the *Yi-jing* as a means of determining an inevitable fate, thus betraying an "inability to admit pure chance" [8: 205]. This draws attention to a profound difference between western logical thinking, which demands a resolution of apparently contradictory positions, and Chinese thinking, which embraces what to a western mind appear to be polarised points of view so that 'truth' may emerge from the dynamic flux in between. Thus "outside-time" chance and "in-time" determinism are able to coexist as complementary rather than competing concepts.

The conceptual roots of randomness also start to unravel when delving more deeply into the pragmatics of stochastic composition with a computer. Any form of stochastic modelling on a computer requires a random number generator, which invariably takes the form of a deterministic iterative function,

a simple algorithm designed to produce a sequence of numbers which have no discernable pattern and which does not repeat. But even the most advanced algorithm will eventually lapse into a repeating cycle, and because there is no pattern discernable by a human agent does not mean that no pattern exists; it just hasn't been uncovered yet. In any case there's no getting round the conceptual predicament that it is a deterministic system masquerading as chance. Early random number generators used in the 1950's were subsequently shown to contain an alarming degree of correlation and order [2: 14-27]. Lejaren Hiller, another pioneer of randomly driven algorithmic techniques in music in the 1950's, told a story of how he spotted unexpected patterns emerging in his music. The nuclear physicists who had condescendingly allowed him to use the slack time on what was then a very rare computer initially refused to accept that their random number generator might not be as random as they thought. Music uncovered what nuclear modelling had failed to reveal (perhaps averting catastrophe on a cosmic scale!).

Further ambiguity emerges when discussing one of Xenakis' favoured models, the Markov Chain. In one of its simplest forms, as a random walk, the output is only statistically predictable, progression is implied but it is reversible, one of Xenakis' tests for outside-timeness. [7: 71] In more complex manifestations a Markov Chain may contain events that form themselves into equivalence classes that give an indication of the general predictability of the chain. These may be *transient* (a class that once left can not be returned to, hence in-time), *alternating* (classes that can be left and re-entered, hence outside-time) or *recurrent* (a class that once entered cannot be left, hence in-time) [3]. Although it provides a valuable stochastic architecture, in general determining whether a Markov Chain is outside or in-time can be problematic.

4. XENAKIS' CLASSIFICATION APPLIED TO CHINESE MUSICAL OBJECTS

4.1 Outside-time: The 12 Lü as benchmark standards

In ancient China it was a matter of critical importance for scholars to fix a standard tuning for the 12 lü, roughly equivalent to the notes of the western chromatic scale. The term *lü* literally means *law* or *rule*, the establishment of which was considered essential for maintaining harmony with the universe and within society. As well as being discussed in theoretical treatises, a lü standard was expressed in the form of an actual physical artefact such as a set of tuned bells used to establish a symbolic imperial benchmark which in ceremonials and rituals could be expressed in an audible, publicly communicable form. The 12 lü were explicitly linked to other areas of scientific enquiry in ancient China, in particular to celestial phenomena and the organisation of the calendar, as an expression of order or rule of law in the cosmos. (The use of the term lü, or rule, in this context has interesting echoes in words used by Xenakis when identifying the influence of quantum theory and Heisenberg's Uncertainty Principal on his own work: " the first thing a composer comes up against is the rule. What is the rule?" [6: 76] by which he likewise meant the ruling order of the cosmos.)

A proliferation of different lü standards, or temperaments were devised at different times and in different regions of ancient China, but a standard employed in a particular dynasty or court became the established norm within its sphere of influence.

The three main types of lü used in China derive from the up-and-down principle (Pythagorean cycle of fifths), from just intonation, and equal temperament [9]. The *up-and-down* principle, first alluded to in *guanzi diyuanpian*, (about 7th century BCE), has deep mythical and symbolic roots. It was implemented by taking a length of pipe as a root pitch, making a second pipe of 2/3 length which would sound a western 'fifth' higher, making the next pipe a third longer at 4/3 length which would sound a western 'fourth' lower and so on, continuing the shortening, lengthening process as required (Figure 1).

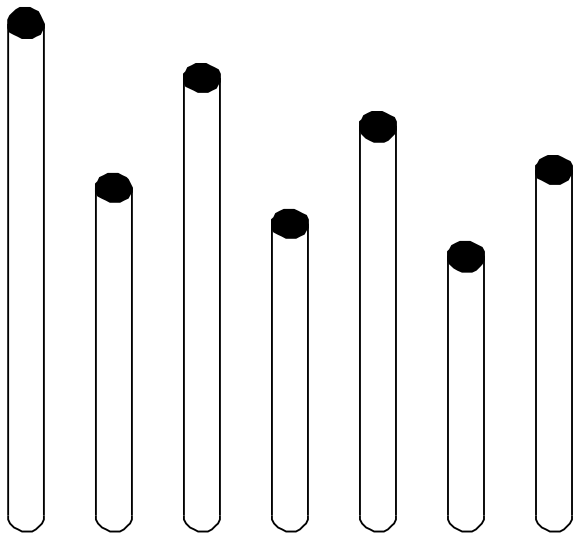

Figure 1: Tuning pipes according to the up-and-down principle

A cycle of five pipes produces the notes of the pentatonic scale (western equivalents C G D A E). Further steps give a full set of 12 chromatic pitches. It was recognised that this method failed to complete a consonant octave to close the cycle, a phenomenon of great fascination to Chinese scholars, who strove to match the 12 lü with the returning year. The gap, the *Pythagorean Comma* of western theory, is roughly proportional to the amount by which 12 lunar months fail to complete the annual solar cycle: a potent cosmic resonance.

Evidence of the use of *just intonation* emerges in the 6th century CE, in surviving performance indications for the ancient Qin (7-stringed zither) that reveals a use of harmonics befitting just intonation. It is assumed, though, that the revered blind musician-sages of antiquity would have been able to manage their tuning by ear without needing to resort to visible markings. There is evidence for the *de facto* existence of *equal temperament* in fretted instruments as far back as the 2nd century BCE, but no actual theory of equal temperament was promulgated until 1584 [9].

4.2 In-time: Pentatonic and heptatonic scales

As with western modes, the classic Chinese pentatonic and heptatonic scales are in-time structures that imply movement away from and towards a tonic, or root. In addition, the names given to notes in the

ubiquitous Chinese pentatonic scale reflect hierarchical structures in the cosmos and society which match their status in melodic usage: the tonic *gong* represents the emperor, the next note *shang* stands for ministers, and so on.

Additional forms of tuning found in regional folk music traditions employ pitches similar to the higher natural overtone series (7th to 12th harmonics) equivalent to a western flattened '7th' and sharpened '4th' (i.e. supposing a C fundamental roughly: Bb↓ C D E F#↓ G). This contains a sequence of five notes that comes close to a whole-tone scale, paralleled in the folk music traditions of Eastern Europe. Curiously Xenakis recognised these oriental influences as a catalyst to Debussy's exploitation of the whole tone scale. This he interpreted as the "rebirth of outside-time preoccupations" in France, which continued "magnificently through Messiaen" to exert a significant influence on Xenakis himself [8: 208]. Even though a context-less whole-tone scale is a perfect example of an outside-time architecture, the actual context from which it derives, and in which Debussy typically uses it, is an assuredly in-time, modal one, embraced by the inescapable gravity of the harmonic fundamental and its satellite drone-like fifth.

4.3 Temporal: Links to the calendar and seasons

The temporal category was of critical importance in ancient China. Successive imperial dynasties defined their own unique, fixed, fundamental pitch known as *huang zhong* or the *Yellow Bell*, determined by scholars to match the heavenly auguries for the epoch. As dynasties changed a new musical standard could replace the old as a sort of universal re-tuning, essential for the maintenance of cosmic harmony. There were genuine fears that if the scholars got it wrong it would compromise the harmony of the state, provoking conflict and social disintegration. The 12 lü could then be determined in relation to the *huang zhong* fundamental and fixed in the form of a set of bells or stone chimes.

In order to 'tune the cosmos' and match the calendar and seasons, in addition to reconciling open-ended solar-lunar discrepancies [4.1 above], scales were also linked to closed cycles of 60. Theoretically there were five forms of the pentatonic scale, each of which could start on any of the 12 lü, making a total of 60 available scales. This parallels in number the 60-year cycle of the Chinese calendar generated by a sequential coupling of the 10 *tiangan* (*heavenly stems*) with the 12 *dizhi* (*earthly branches*), an arrangement that continues to the present day. This 60-fold cycle coupling was also used for counting days and hours. Ancient texts from the *Qin and Han Dynasties* (from the third century BCE) describe attempts to associate the 12 lü with the five Chinese elements, matching the 60-fold cycle to years, days and hours as a means of establishing auspicious moments for undertaking significant activities such as travel.

4.4 Ambiguities and boundaries: The Marquis Yi bells

Although the status given to the "outside-time" lü standard implies a coherent theoretical construct, ostensibly definable, say, through Xenakis' Sieve Theory, and from which practical "in-time" modes and tunings should be derived, evidence suggests that the opposite is the case. The ideal is abstracted from the pragmatic.

A study of the celebrated set of *Marquis Yi* bells from the 5th century BCE [1] suggests that their tuning was established with the aid of a 5-string Qin-like instrument discovered in the same tomb. (Usually a Qin has 7 strings, but since the last 2 are tuned one octave higher than the first two, five strings are sufficient for setting a tuning standard.)

Each bell in the set can be struck on the front or on the side to give two distinct notes related by either the 'larger third' or 'smaller third' of just intonation. According to Chinese musicologist Cui Xian, the tuning of the bells reveals an architecture derived from *zhengdiao*, one of the commonest modes of Qin tuning employed in performance. The open strings of this mode are roughly equivalent to the notes C D F G A in western notation (Table 2). These notes are established by the up-and-down principle, or cycle of fifths, tuned with the assistance of simple harmonics sounded on the strings. To establish the other four rotations of the mode (the *manjiao* mode, *mangong* mode, *ruibin* mode and *qingshang* mode) notes equivalent to E, B, Bb, and Eb are determined by loosening or tightening the relevant string by one lü (lü in this context meaning roughly one semitone) always tuning with reference to the other strings' harmonics. These 9 core notes further branch out to complete a network of tunings derived from a combination of pure fifths and just intonation 'larger' and 'smaller' thirds. Hence the "outside-time" formal standard is derived from the "in-time" modal practice.

Strings:	**1**	**2**	**3**	**4**	**5**	
main mode	C	D	F	G	A	tuned to perfect intervals e.g. F-C-G-D-A
manjiao mode	C	D	**E**	G	A	3rd string "loosened" by one lü
mangong mode	**B**	D	E	G	A	1st string "loosened" by one lü
ruibin mode	C	D	F	G	**Bb**	5th string "tightened" by one lü
qingshang mode	C	**Eb**	F	G	Bb	2nd string "tightened" by one lü

Table 2: Qin tuning method following Cui [1:172-174]

5. MULTIPLE TEMPERAMENTS

Characteristic of the music of Ancient China and contemporary Chinese folk ensembles is the simultaneous use in performance of tunings derived from the open cycle of fifths, just intonation, equal temperament, and the higher overtone series. To a western listener this 'sweet-and-sour' combination is bewildering, and even distressing, but it is consistent with the broader axioms of Chinese thought in its appreciation of what to a western mind are contradictory positions. Chinese musicologist Liang Mingyue observes: "This poly-temperament phenomenon is an important trait in Chinese music, providing an 'out-of-tune' flavor. It is as essential an ingredient in Chinese music as spice is to its cuisine." [4: 23] It is interesting that this acoustic phenomenon could reasonably be modelled as a subtle form of sieve, resulting from overlapping logical constructions which match the theoretical underpinning of Xenakis' meta-musical prescriptions.

In addition the improvisatory embellishments of heterophony and relaxed timing of Chinese ensemble performance result in a rich, grainy texture, which has a perceptual equivalence to Xenakis' sound clouds: "these clouds can be heard within a narrow or wide ambitus … If you can blend sounds into a kind of

mixture, leading away from the tones of an individual instrument, it becomes pure timbre, a *corpus delecti*!" [5: 12] Xenakis recognised how these qualities in his own work are paralleled in traditional Asian music, which, he observed, "has no constant pitch and the sound is always moving around it." [6: 69] It implies that a familiarity with Asian music aids appreciation of Xenakis' music. Equally, the reverse might apply. Westerners who find Chinese ensemble music problematic should not listen to it as they would listen to Mozart or Stravinsky, but as they would listen to Xenakis.

6. CONCLUSION: BRIDGING CULTURES

It is evident, then, that in holding a mirror of Chinese music up against the music and theories of Xenakis some striking parallels and divergences emerge, which help to illuminate some of the more recondite aspects of Xenakis' thinking. It is in addressing the claim to a cross-cultural universal validity to Xenakis' theories that the comparison becomes particularly valuable, providing a measure of defence against Bernard Teyssèdre's 'devil's advocate' charge of "cultural imperialism" [7: 83].

Xenakis made a brave and largely successful attempt to escape the suffocating modernist confines of 'new' music in the west in the middle of the 20th century by reaching outside of the box, across time into the past, across space into other musical cultures, and into the parallel cultural universe of contemporary science. As a composer operating within the western "logico-rhetorical" concert tradition Xenakis inevitably produced music for a market, but in producing music intended to reflect an understanding of the nature of the universe, rather than just for entertainment or self-expression, his work is close in spirit to the nature of the Chinese Qin scholar-performers. Their performances had a ritual quality intended to promote moral and intellectual edification, fostering a sense of wholeness for themselves and their intimate circle by reflecting cosmic harmony. Interestingly, the most venerated Qin scholars of antiquity were blind; a poignant parallel with Xenakis whose own vision and hearing was severely damaged as a result of being hit by a British tank shell in Athens in 1945. He confessed: "Because of my weakened senses I can't immediately grasp the surrounding world. I think that's why my brain has turned more and more towards abstract thinking" [6: 48]

Xenakis' theories may not always be completely watertight on closer examination, but therein lies their strength. In the same way that Chinese thinking is sustained in a balance of opposites, it is the potent tension and dynamic of paradox that contributes to the power of Xenakis' thought and composition. The "in-time' ghosts which inevitably hover in the background of Xenakis' "outside-time" generative architectures provide rich, multiple layers of implicit references and contradictions. It helps to account for the unique vitality of his music.

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