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Symmetrical Structures in Xenakis's *Okho*: At the Intersection of Mathematics and Literature*

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ABSTRACT: While there are abundant discussions of Xenakis's works through the lens of mathematics, formulated from the composer's own treatise *Formalized Music: Thoughts and Mathematics in Composition* (1992), scholars have rarely addressed how his interest in Greek literature manifests in his compositions beyond programmatic titles. Xenakis reveals his fascination with classical antiquity in numerous publications, yet critics have not explored how his literary interest intersects with his compositions in structural terms. An examination of classical Greco-Roman literature reveals a frequently used rhetorical structure prevalent among classical authors—*chiasmus*. This structure emphasizes the centermost clause surrounded by parallel clauses stated in reverse order. This article analyzes Xenakis's *Okho* (1989) for three djembes through the lens of symmetrical structures, unveiling a cohesive narrative centered on the contrast of stability and chaos achieved through construction and deconstruction of palindromes and chiasmi. These processes evolve over time; smaller chiasmi initially embedded within a single bar expand into larger multi-measure structures constructed through Fibonacci sequences. Such structures are systematically diminished and dismantled as the piece approaches its conclusion. By examining the intersection of intervallic structures with symmetrical structures, the once elusive connection between Xenakis's mathematical processes and Greek literature comes to light. Xenakis bridges mathematics and literature, harmonizing modernity with classical antiquity by integrating intervallic structures into his chiastic structures.

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Introduction

[0.1] Most scholarship centered on Xenakis carefully balances two impulses observed in his artistic persona. He is, for one, viewed as a composer-architect profoundly interested in Ancient Greek literature.(1) At the same time, theoretical analyses of Xenakis's corpus tend to focus on mathematical processes. Xenakis's self-publications as well as commentary from later theorists are undoubtedly crucial to understanding the composer's compositional conceptions.(2) However, the

abstract nature of mathematical theories corresponding to each composition also make it difficult for performers to translate Xenakis's semantics to interpretation. One composition in particular faces this dilemma, namely the 1989 piece *Okho*, written for three djembes.

[0.2] To help bridge the conceptual gap between biographers, interpreters (performers), and theorists, we will call upon an analysis of *Okho* more specifically relevant to performers. This bridge does not lie solely in the mathematical aspect of architecture; rather, it fundamentally resonates with Xenakis's heritage, specifically the composer's love for Greek mythology and poetry. Discussions of symmetry found in ancient Greek poetry will shed new light on Xenakis's work. This new viewpoint, moreover, will bestow significance to current musicological scholarship on Xenakis by linking his work with his heritage. Additionally, it will aid performers in perceiving *Okho* in a coherent and concrete manner, in contrast to the more abstract means afforded through pure mathematics.

Background

[1.1] Tom De Cock's 2015 analysis of *Okho* reveals Xenakis's different compositional approaches that involve both sieves and stochastic distribution of timbres using his software General Dynamic Stochastic Synthesis (GENDYN). Both methods, it should be noted, are clearly validated by the composer's own sketches. Xenakis's use of sieve theory, which are modular arithmetic structures based on pitches and rhythms, has been investigated by key scholars such as Nouritza Matossian (1986), James Harley (2004), Dimitris Exarchos (2008; 2019), Exarchos and Daniel Jones (2011), Benoît Gibson (2011), and José Besada (2022).(3) Barthel-Calvet, in particular, reveals Xenakis's application within scales and modality, while Gibson (2011) reveals their application to rhythmic material.(4) Xenakis's percussion compositions have also been analyzed using a similar method, as evidenced by Besada, Barthel-Calvet, and Pagàn Canovas's 2021 analysis of *Psappha*. Peter Hoffmann's 2000 article about GENDYN provides insight into earlier research-creation projects facilitated by Hoffmann and Xenakis in the 1990s.(5)

[1.2] As well-informed as De Cock's study is, his sieve analysis tends to overlook the significance of Xenakis's semantics in his compositional process. More specifically, it may not fully explain why the music holds meaning for both Xenakis himself and the performers. A significant issue arises in the inconsistency of its application in the final form of his music, as noted by Gibson (2011, 159). Similar questions arise when considering his stochastic processes, which lean on chance and statistics even with certain algorithmic consistencies.(6) Similarly, De Cock (2015) underscores the necessity for more discussion in the context of *Okho*, suggesting that Xenakis might have altered orchestration as a final step to "add to the structure and clarity to the piece."

[1.3] There is considerable difficulty among scholars in contextualizing *Okho* within Xenakis's broader corpus. While De Cock provides valuable insights into the piece through his focus on sieves, Harley 2004 views the piece in terms of its "Melody, Harmonic Color, and Non-Linear Form." Harley's decision to include the work in this chapter is all the more remarkable in light of two facts. The first is that *Okho*, as a composition for three djembes, does not inherently incorporate defined melodic or harmonic elements; the second is that the chapter preceding it is expressly titled "Sieves, Ensembles, and Thoughts of Death" (Harley 2004, 108).

[1.4] A significant number of analyses in Xenakis's works portray the composer's technique as the epitome of applied musical mathematics. In doing so, however, they overlook another branch of Xenakis's interests, namely his passion for Greek poetry and in literature. In fact, it was not mathematics but rather ancient Greek poetry that initially captured Xenakis's attention during his early education. According to Nouritza Motossian,

> In the library he discovered a retreat from which he did not stir for hours and hours, reading voraciously English and French literature of the 19th century; the complete works of Victor Hugo including his poetry, Flammarion's astronomy, classical Greek poetry and drama, Pindar, Anacreon, and Sappho. A gift for mathematics and natural sciences emerged as he became more involved in classwork. But instinctively he was drawn to classical literature and philosophy in which he found a natural hideout and a substitute for the real world. (Matossian 1986, 14)

If Xenakis was drawn to literature—specifically the disciplines of poetry and philosophy—as a means to escape reality, then it is reasonable to assert that this art form plays a central and underappreciated role in this composer's art.

[1.5] Xenakis's passion for Greek literature, which was fostered in his childhood education, manifests throughout his compositions for percussion. He references Greek mythical figures and sources, such as Persephone (*Persepphasa*, 1969), Sappho (*Psappha*, 1986), and *Pleïades* (1979).[(7)] Persephone and Sappho are mentioned in both Xenakis's 2015 interview published by De Cock and in Matossian 1986, where the composer enlightens us about Sappho and Homer (the author of "Hymn of Demeter").

[1.6] It is, on the whole, quite striking how few investigations exist linking Xenakis's music with Classical Greek poetry. And existing comparisons often fail to connect its literary characteristics with its structure. For example, Owen Phillip Rockwell (2015) succeeds in linking *Psappha* with Sappho in terms of the poet's iambic rhythm but falls short in identifying any further symbolism in the music. This lacuna is all the more regrettable for the reason that structure in ancient Greek poetry directly informs hermeneutics and hierarchy, and therefore meaning and significance.[(8)] This fact may partially explain why Xenakis became interested in classical Greek literature in the first place; Xenakis is intrigued by the hermeneutics presented by its architecture.

[1.7] Xenakis's interests in both mathematics and Greek literature present a challenge for analysts seeking to understand both his compositional processes as a whole and *Okho* in particular. While current theoretical interpretations work to align his sketches with his career as a civil engineer and architect, there is also a need to consider if Xenakis's references to Classical Antiquity factor into his compositions beyond the programmatic titles. My analysis of *Okho* offers precisely this alternative perspective. My approach, it should be noted, does not counter any research already conducted in light of his mathematical methods; rather, it incorporates new elements to create a new method that better resonates with the composer and better informs theorists and performers.

Poetic Architecture: Chiasmus in Classical Literature

[2.1] Literary scholars (Thomas 2013, Bakker 1997, Bierl 2019) note structural consistency in ancient texts, which informed their semiotics. Modeled after the Greek letter X (chi), so-called "chiastic" structure centers around a principal theme that is literally surrounded by supplementary themes. Each supplementary theme is mirrored by a corresponding rhetorical or conceptual element placed symmetrically on the opposite side of the central theme. Chiasmi in literature appear in both small and large-scale forms. The smallest structures are often contained within a single sentence, created through grammatical inversion and the repetition of corresponding phrases. Large-scale chiastic structures may span multiple lines or stanzas, with their components often linked thematically through hermeneutic analysis. In music, chiasmus can be compared to the arch form (ABCBA), though unlike the arch form, chiasmus does not necessarily rely on direct repetition of corresponding phrases.[(9)]

[2.2] One of the simplest and well-known chiastic sentences is "all for one, and one for all" found in Alexander Dumas's *The Three Musketeers* (trans. Robson 1899, 108). This idiom is a two-phrase sentence in the form ABBA. Smaller phrases like this are conceptualized using a diagram of the Greek letter X as the reference, as shown in **Example 1**. The phrase is separated and linked with each end of the cross to demonstrate its parallel nature. The hermeneutics presented by the example emphasizes the "one" instead of the "all": the individuals' actions are understood to shape and represent the whole, rather than the reverse.

[2.3] Similarly, Sapphic poems and Homeric Hymns, the inspirations for titles *Psappha* and *Persephassa*, have long been interpreted with chiastic structuring. For larger chiastic structures, the reference point lies in the thematic content represented by a group of lines or stanzas, rather than in the individual phrases. The text below presents an example of Sappho's well-known fragment LP16, referencing an interpretation offered by G.H. Els and J.H. Barkhuisen (1983, 23–24).[(10)] I have reformatted the poem in two versions: The version on the left displays the translated poem with

original stanza breaks, and the second version reorganizes them to reflect Els and Barkhuisen's interpretation:

Some say an army of horsemen,
some of foot soldiers, some of ships,
is the fairest thing on the black earth,
but I say it is what one loves.

It's very easy to make this clear
to everyone, for Helen,
by far surpassing mortals in beauty,
left the best of all husbands
and sailed to Troy,

mindful of neither her child
nor her dear parents, but
with one glimpse she was seduced by
Aphrodite. For easily bent . . .
and nimbly . . . [missing text] . . .

has reminded me now
of Anactoria who is not here;
I would much prefer to see the lovely
way she walks and the radiant glance of her face
than the war-chariots of the Lydians or
their foot soldiers in arms.

Some say an army of horsemen,
some of foot soldiers, some of ships,
is the fairest thing on the black earth,

but I say it is what one loves.
It's very easy to make this clear
to everyone, (6a)

for Helen, (6b)
by far surpassing mortals in beauty,
left the best of all husbands
and sailed to Troy,
mindful of neither her child
nor her dear parents, but
with one glimpse she was seduced by
Aphrodite. For easily bent . . .
and nimbly . . . [missing text] . . .

has reminded me now
of Anactoria who is not here;
I would much prefer to see the lovely
way she walks and the radiant glance of her face

than the war-chariots of the Lydians or
their foot soldiers in arms.

[2.4] In the article, Els and Barkhuisen offer a thematic simplification of the poem by lines. Lines 1–3 and 19–20 relate to each other in that they denote military objects. However, lines 1–3 differ from 19–20, in that the first three lines are addressed in a general manner while the last two lines provide specific examples. Lines 4–6a and 15–17 manifest in a similar manner as the first three lines in that the former is vaguer than the latter. This section compares one lover to another named Anactoria. Between lines 6b and 14, readers are introduced to the myth of the Trojan war and the relationship of Helen and Aphrodite within it.(11) Effectively, the chiasmus is structured as follows:

A Military Objects in General (1–3)
B Love Object in General (4–6a)
C Myth (6b–14)
B' Love Object in Particular (15–18)
A' Military Object in Particular (19–20)

[2.5] As John Welsh (1999) notes, the deeper significance of chiasmus stems from its parallelism which segments the narrative into multiple related parts. This structuring aids memorability in the oral transmission of traditions and knowledge to the successive generations. The organizational potential of chiasmus can also be seen to apply to Xenakis's compositional procedures, where it serves to communicate his mathematical conceptions to the audience. De Cock (2015) perceives this possibility by mentioning Xenakis's final alterations to add "structure and clarity to the piece." Welsh also comments on the musical potential behind this literary structure and draws a parallel between writers and composers: "skilled writers would have no difficulty applying this form, and artistic composers would seize upon such an opportunity. . . to take great advantage of the powers which the form itself affords" (1999, 6–7).

[2.6] Readers at this point have likely connected the concept of chiasmus to that of palindromic sequence. Palindromes are sequences of numbers or letters that manifest in the same order forwards and backwards. Identical characters are placed at a similar distance away from the center,

similarly to how a chiasmus is structured, but now numerically. Palindromic sequences are frequently referenced in analyses of Xenakis's music, for example in Harley 2004 (123, 160, 184), Rockwell 2015 (32, 53–54) and De Cock 2015, the last of which identifies them in mm. 60–79 in *Okho*. Following from this, one may ask why I have prioritized chiasmus over palindromes in analyzing *Okho*. One answer, again, relates to the hermeneutical potential of chiasmus. Palindromic structure emphasizes symmetry over all; the chiasmus, on the other hand, introduce hierarchy, thus emphasizing the center component. A further reason to prioritize chiasmus over palindromes concerns analytic flexibility. Palindromes demand exact symmetry, where parallel parts must be identical and restated. In contrast, chiasmus does not require exact repetition. Corresponding parts are frequently—in fact *preferably*—differentiated in rhetoric while remaining similar in theme. From a performer's perspective, approaching Xenakis's works with chiasmus structures in mind opens up new possibilities of hierarchical parsing that can inform local phrasing and global decisions on pacing and energy.

Contextualization: Gibson's Sieve Theory for Works Written for Percussion

[3.1] Moving past the mathematical and literary background, it is necessary to further introduce the inspiration for my analytic approach, that being Benoît Gibson's 2011 discussions of sieves for works written for percussion. Appearing as the third book in the *Iannis Xenakis Series*, Gibson's publication presents an extensive analysis of the composer's work and occupies a distinctive place in the series for its focus on compositional methods drawing from Xenakis's 1992 *Musiques Formelle*s. I am particularly interested in how Gibson analyzes intervallic structures, which are used to observe elementary sieves in two aspects, specifically melody-scale and rhythm-timbre. In the melodic aspect, an elementary sieve defines the relationship between a reference note to a given scale as a set of numeric sequences. The rhythmic-timbral definition establishes a correlative relationship manifesting between played notes, rests, and changes in timbre when playing a particular percussion instrument. The melodic-scalar aspect of Gibson's discussion uncovers the roots of Xenakis's sieve theory (elaborated below), while the rhythmic-timbral aspect expands its definition from the melodic. The following discussion, in reflection of this progression of concepts, will introduce aspects of melodic/elementary of sieves before moving to explain their rhythmic-timbral aspects.

[3.2] Gibson defines melodic sieves as relationships between intervals within a single scale. These relationships are represented in a numeric sequence arranged as modulus and indices (Gibson 2011, 83–84). Sieves can be thought of as divisions, with modulus as the divisor and indices as remainders. Its formal arrangement, known as *residue class* and *index*, is represented as follows: the main number denotes the modulus, and the smaller subscript (*n*th term) indicates the indices. The multiplier is hidden since its arrangement include the entire sequence. Gibson (2011, 84) presents a simple example of residue class 3 index 2, which is represented as 3_2: {2, 5, 8, 11, 14. . . }. Their multipliers are: {0, 1, 2, 3, 4. . . }. The sequence may also be applied for negative integer multipliers, for example {–4, –3, –2, –1, 0. . . }. The outputted sequence in this case is {–10, –7, –4, –1, 2. . . }. Once the numerical sequences are defined, they are translated to musical notation (82). A particular note becomes the reference, after which other notes are numerically represented factoring the interval away from it. Gibson's example applied in *Nomos Alpha* (1965) defines a quartertone as an elementary melodic sieve. Applying the previous example of residue class 3 index 2, the results of combining both negative and positive integers are as follows: {–10, –7, –4, –1, 2, 5, 8, 11, 14}. If the D4 note becomes the reference point, the translated pitches become: A♭3, B𝄳3, C4, D𝄲4, D♯4, E𝄰4, F♯4, G𝄰4, A4.

[3.3] The rhythmic-timbral aspect of sieve theory according to Gibson (2011, 103–7) refers to elementary sieves as a particular note-value and its distance away from the next played note. Gibson defines an elementary rhythmic sieve as a numeric sequence based on time, referring to the positioning of notes from the reference point in note values. This approach expands from the melodic definition of an elementary sieve—a numeric sequence denoting notes' positions from the reference pitch in intervals—to the temporal domain. **Example 2** reproduces Gibson's Example 6.1 (2011, 104); as Gibson notes, the numbers presented in the example are based on their rhythmic placement from the first beat of m. 222. The intervallic structure starting from {1–1–1–3. . . } in

reference to Example 2 is drawn using an identical methodology seen in Gibson's Examples 3.13 and 3.15 (56). For both examples, each number represents the distance between notes and following rests in sixteenth-note values starting from 1. The rhythmic sequences, much like their melodic counterparts, provide a structural framework that ties the timbral and rhythmic elements of *Okho*, which will further support my analysis to the work.

[3.4] As applied to analysis, Gibson first discusses rhythmic patterns and their numeric sequences through a pattern drawn from *Synophaï* (1969) (**Example 3**). The numbers prescribed in this example indicate the distance away from the next note using sixteenth-note values as reference, accounting both played note values and rests. Gibson uses a similar method for comparing *Persephassa* and *Antikhthon* (1971, **Example 4**). The scope of analysis expands to include multiple lines, yet Gibson still concentrates on each timbre and their recurrence to draft its numbers. The second transformation between *Idmen B* (1985) and *à l'île de Gorée* (1986) is analyzed using an advanced method from Example 4. In **Example 5**, Gibson's sequence is based on the rhythmic distance accounting all of the lower timbres as a collective entity, instead of measuring each timbre individually as in Example 4. The lower timbres indicate notes written in all spaces below the first line, while the highest timbre complements these lower timbres to accomplish Xenakis's desired sequences. The key difference in Gibson's methodologies in Examples 4 and 5 is in their order. Example 4 is analyzed at the primary level, considering each timbre separately; whereas Example 5 is analyzed using a more holistic approach to include all timbres at the secondary level.

[3.5] My analysis of *Okho* draws on Gibson's dual methodologies discussed in his chapter 3. Elementary rhythmic sieves are analyzed in the primary level for the earliest and latest segments, where relevant symmetrical structures actively form and disintegrate. The secondary level analysis is applied where relevant symmetrical structures span multiple measures, and the analysis incorporates multiple timbres when counting. The two levels of analysis help illuminate the gradual process of constructing and deconstructing symmetrical structures within the piece.

[3.6] These symmetrical structures are usually confined within a single bar, and each timbre becomes the focus of the analysis. The secondary level analysis is applied where relevant symmetrical structures span multiple measures, and the analysis incorporates multiple timbres when counting. Expanding on Gibson's intervallic structures, I introduce a tertiary level of analysis, focusing on symmetrical structures spanning more than five measures (Gibson 2011, 104). Full sets of numeric sequences based on rhythmic intervals are analyzed and compared against each other and mapped in a large-scale form diagram. Last, I introduce a secondary axis in my typology, distinguishing between chiastic and palindromic structures. While my examination of palindromic structures will reinforce De Cock's findings, my analysis of chiastic structures will offer new analytical perspectives previously unexplored.

[3.7] The three-level structural model provides clarity in categorization by identifying each type of symmetrical structure. Before moving forward with the analysis, however, it is important to briefly address the model's limitations along with their concomitant impact on the typology. First-order analysis is particularly better suited for identifying palindromic structures than chiastic structures because of the intricacies in its method. Conversely, third-order analysis is limited in finding palindromic structures due to the complexity of mirroring multi-measure patterns. As a result, the primary and the tertiary-level analyses are intended to focus on one structure type each. The secondary level, unlike the primary and tertiary, offers greater flexibility, as the structures are small enough to establish both chiastic and palindromic patterns. In total, four types of structure will be discussed, as summarized in **Example 6**: first-order palindromic, second-order palindromic, second-order chiastic, and third-order chiastic.

[3.8] Xenakis's manipulation of tempo throughout *Okho* is the final element that shapes how its structural content is conveyed in performance. Tempo will not be classified separately, since its inclusion creates overly specialized and numerous typologies. Nevertheless, tempo is one of the crucial aspects for both performers and listeners, since Xenakis employs it to contrast sections composed with GENDYN, often quicker paced than segments which embed symmetrical structures. As a result, the adjusted speed allows performers to play chiastic and palindromic structures much more accurately than randomized segments. In addition, audience members can

easily perceive these structures owing to the fact that relevant passages are written at a slower tempo.

Analysis: Introduction

[4.1] *Okho* was commissioned by the Festival d'Automne à Paris, commemorating the bicentennial anniversary of the French Revolution in 1789. The piece was premiered by Trio le Cercle, featuring members Willy Coquillat, Jean-Pierre Drouet, and Gaston Sylvestre. *Okho* is written for three djembes and African bass drum. The djembes can be played either through hands or drumsticks, depending on the section.

[4.2] Each of the three individual performer scores for *Okho* is realized as six lines, arranged more specifically as two staff systems with three lines per system. The upper staff indicate playing on the edge of the drum, while the lower staff is played in the center of the drum (**Example 7**). (Respectively, these different beating spots produce the sounds of partials versus the fundamental frequency [bass] of the drum.) The sounds are further differentiated on each line as indicated in the score. On the edge, the sounds include *bord claqué résonnant* (resonant slap), *bord claqué sec* (dry slap), and *bord clair* (clear/open tone). On the bass, the sounds are *basse claquée* (slapped bass), *basse normale* (normal bass), and *basse étouffée* (muffled bass).[(13)]

[4.3] *Okho* is divided into four large-scale sections, each distinguished by varying aesthetics of timbre and tempo. The first section, spanning mm. 1–58, is characterized by a random assignment of six timbres interspersed with symmetrical phrases. These randomized and symmetrical segments are distinguished by their tempi—120 beats per minute for the randomized parts and 56 beats per minute for the symmetrical ones—as well as with the introduction of new playing techniques for symmetrical sections. The second section, from mm. 60–80, features quasi-palindromic structures using the Fibonacci sequence (2015). In the third section, mm. 80–116, Xenakis instructs performers to use sticks to play the *bord* notes, while the *basse* notes are played with the hands. This section marks the most distinct timbral contrast between the stick and hands. The *bord* notes in the manuscript reflect the positioning of the stick between the center and the edge of the drum, with the lower note closest to the center and the highest note nearest to the edge. The final section, from m. 117 to the end, is characterized by polyrhythms, predominantly featuring a three-against-four pattern between the left and right hands. This material is reminiscent of *Rebonds* (1987–89), one of Xenakis's most well-known solo works for multipercussion. Additionally, this section introduces two moments where Xenakis prescribes differing odd polyrhythmic ratios for all three players, suspending listeners' sense of time by blurring the perception of pulse and timbre.

[4.4] I begin my account at the start of the piece, where Gibson's analysis of intervallic structures (his Example 3.11) is readily applied by accounting for the timbral changes for performer A (**Example 8**). The first nine measures display a continuous, repeating pattern of five sixteenth notes, using three *bord* and two *basse* notes. The accentuations reflect the timbral changes of three and two sixteenth-note values, similarly to players B and C's rhythmic figures based on three sixteenth-note values. According to De Cock (2015), performers B and C act to disrupt performer A's initial pattern in mm. 2 and 3 either by altering A's *bord clair* note into a *bord claqué sec* or by adding notes to form a seven-note pattern instead of a five-note one. The significance of the five-note pattern grows when considering its repetitions in the first nine measures. Initially repeated ten times, this pattern is briefly disrupted in m. 4 before being repeated fifteen more times until it is disturbed permanently from m. 10. Now consider the *bord clair* and *basse étouffée* accentuations from the first two repeats and in every repeat from m. 7–9. The ten and fifteen repetitions of the pattern form multiples of two and three, with five as a common divisor. The relationship between player A's accentuations, players B and C's rhythmic patterns, and the five-note patterns are established mathematically, which could then be interpreted as one correlated segment.

[4.5] The arrangement suggests that the two repetitive sections from mm. 1–3 and mm. 5–9 form an enveloping segment of a chiasmus, with mm. 4–5 serving as its center. In the center, Xenakis introduces a sharp contrast against the stability provided by the repeated patterns by inserting three new timbres in random order: *bord claqué sec*, *basse claquée*, and *basse normale*. Viewed in hermeneutic terms, the center of the structure can be seen as representing the embodiment of chaos

in a seemingly ordered structure, thus bestowing more significance in relations to the hierarchy within the chiastic structure. Performers B and C then attempt to disturb A's patterns, succeeding in short order. After a brief chaotic moment, the five-note pattern is quickly rebuilt to be repeated until m. 10.

[4.6] In my proposed tripartite typology, the structure presented embodies a secondary order chiastic structure. The analysis spans multiple measures, but more importantly incorporates multiple timbres, instead of considering each timbre individually. The following sections of the article will identify various types of symmetrical structures presented throughout the piece, organized as first-, second-, and third-order structures.

Analysis: First-Order Structures

[5.1] The first-order symmetrical structures observed in *Okho* are palindromic, with their sequences calculated using individual timbres. These structures appear in the very beginning and the end of the piece—first in a formative state, where traces of symmetry begin to emerge, and later in a process of gradual deconstruction. Gibson's methodology used in his Example 3.7 (see Example 4) to compare *Persephassa* and *Antikthon* is applied here to calculate the interval between each respective timbre.

[5.2] Performer A plays the first structure in m. 10 (**Example 9**). This structure is more difficult to hear as it is concealed in the part's *bord claqué résonnant* sound stream. The performer can observe an upward pattern of *bord* notes beginning at the end of m. 9 (the "and" of 4), spaced by two or three sixteenth notes in the *basse* timbre. A clear pattern emerges when these three *bord* notes are separated and counted based on the number of sixteenth notes before their reappearance. For *bord clair* notes, the sequence is 9, 9, 10, 10; for the *bord claqué sec*, the pattern is 9, 10, 9, 10; and for *bord claqué résonnant*, the sequence is 9, 10, 10, 9. The *bord claqué résonnant* pattern forms a palindrome, with the node of symmetry separating the two 10s. This structure is remarkable not only in that it appears early in the piece within the stochastic soundscapes, but that it is one of very few such structures to embed a clear pattern of an upwards *bord* notes.

[5.3] The next first-order structure we observe, one of the last quasi-symmetrical structures to appear in the piece, emerges in m. 121 during performer C's solo passage (**Example 10**). The score reveals two arch-like structures, with analysis of the individual timbres uncovering remnants of a palindromic structure. The first arch structure begins at the start of m. 121, with the progression from *basse étouffée*, *basse normale*, and *basse claquée* to four *bord clair* and eight *bord claqué sec* notes; this is followed by a descent to *basse normale* and *basse étouffée* on beat 4. The second arch starts with a *basse étouffée* on the first triplet followed by *basse normale* and eight *basse claquée* notes, then three *bord clair* notes, and finally *basse claquée* and *basse étouffée* just before beat 4. The symmetry becomes apparent when observing the crossover between the intervals of four *bord clair* and eight *bord claqué sec* notes with eight *basse claquée* and three *bord clair* notes. If it were that this structure was functioning to embed an axis of symmetry, the sequence for this quasi-palindrome would be (4, 8, 8, 3). But it is not. Instead, the structure represents deconstruction newly birthed from the stochastic soundscapes and, as such, is placed towards the end of the piece to contrast with the previous structure.

Analysis: Secondary-Order Structures

[6.1] Secondary-order structures are modeled on Gibson's analysis from his Examples 3.11 (see Example 5), 3.13, and 3.14, in which multiple timbres are accounted for. While first-order structures are restricted to purely palindromic sequences, secondary-order structures are more flexible. On account of it encompassing both chiastic and palindromic structures, this category of structure is by far the most prevalent in Xenakis's output.

[6.2] The first second-order structure is chiastic in mm. 16–17 (**Example 11**). This is a solo passage of performer B, characterized by a prevalence of *bord claqué résonnant* sounds with interjections of other timbres. Between the fourth beat of m. 16 (the "and" of 4) and the first beat of m. 17 (the "e"

of 1), there is a concentrated disturbance by three sounds: *basse claquée*, *bord clair*, and *bord claqué sec*. These sounds constitute the center of the chiasmus, which is bookended by 14 sixteenth notes in the beginning of m. 16 and 14 sixteenth notes after (including the fourth beat of m. 17). Of further note is the ordering of *bord claqué résonnant* sound followed by *basse claquée* sound, which surrounds the chiasmus in the fourth beat of m. 26 and the first beat of m. 27. De Cock (2015), in their prior analysis of *Okho*, hypothesized that Xenakis may have inserted solo passages in the final stages after randomizing orchestration using GENDYN (2015). This evidence provided by this passage would seem to support this presumption if Xenakis intended to create a chiasmic structure. In contrast to previous structures, where Xenakis concealed the symmetry within the overall texture, here he appears to present it more overtly.

[6.3] The next passage to be considered is mm. 25–27 (**Example 12**), where the music clearly presents two chiastic structures. In this case, the rhythmic groupings of triplets and two thirty-second notes are of particular importance. In m. 25, the center of the chiasmus lies in the third beat, with player A's rhythmic grouping surrounded by all three players' *basse étouffée* and *basse normale* notes. The rhythm cascades from player A to C, then back from C to A, without any overlaps or rests. The latter of the two chiastic structures, spanning mm. 26–27, is more challenging to discern, as the *basse* notes must be combined to form the entire rhythmic grouping. Performer C serves as the center of the chiasmus, starting from the sixteenth note before the third beat and continuing to the triplet before the fourth beat. Player A's first seven notes in m. 26, along with their rearrangement spanning the last sixteenth note to the first beat in m. 27, make up the two ends of the second chiasmus. The rhythms in between the three constituent parts of the chiasmus are fragmented versions of their own, performed by player B. Player A's *bord* sounds in this passage manifest as a retrograded rhythmic figure, with the initial statement in m. 26 being restated in m. 27. The two symmetrical structures, clearly visible in the score, are constructed from similar elements of *bord* and *basse* notes. This example best exemplifies Xenakis's method of gradually constructing and deconstructing symmetrical structures.

[6.4] The next chiastic structure, appearing in m. 32, occurs by virtue of a complex set of rhythms played by all three players (**Example 13**). On the surface, this measure may seem chaotic, with layered polyrhythms created by all three performers; however, beneath this complexity lies a double-layered chiasmus. To clarify the analysis, the rhythms in the example are represented numerically, with each integer indicating the number of notes played in each eighth note segment. The first chiasmus is found when comparing the number of notes played by performers A and B. Performer A's sequence (5 [3+2], 3, 6 [2+4], 3, 5 [3+2], 4, 4) mirrors that of player B (4, 4, 5 [2+3], 3, 6 [4+2], 3, 5 [2+3]). What is further striking is that the near exact retrograde of the first half of player B's material, in both rhythm and timbre, occurs as the last half of player A's material sounds. At the center of the chiasmus, a unison sixteenth-note triplet stands out, providing sudden clarity amidst the otherwise dense textures. This clarity becomes even more pronounced when player C is integrated into the polyphony. Beat three of m. 32 features a doubled sixteenth-note triplet figure played by parts A and B, juxtaposed with the four thirty-second notes played by performer C. This central figure emerges much more clearly here than in the outer layers, since the inclusion of player C introduces a third layer of polyrhythms in addition to performer A and B's parts. This example is the most compelling representation of a smaller-scale chiastic structure: the colored crosses in the diagram visually reinforce an "all for one and one for all" interpretation.

[6.6] **Example 14** represents a portion of another quasi-palindromic structure noted by De Cock (2015), this one appearing in the second part of the piece. The structure is constructed by arranging Fibonacci sequences using thirty-second notes. The beginning of these structures are marked by *bord claqué resonant*, and the distance to each event occurrence is calculated from 1. The resulting sequence from mm. 60–61 is as follows: 21, 13, 8, 5, 3, 2, 1, 1. The sequence then retrogrades from 1 to 21, ending with a roll which acts as an axis of symmetry. Following the roll, another sequence starts from mm. 62–63 with 1, 1, 2, 3, 5, 8, and 13. As the piece progresses, the sequence is cut by one position, beginning and ending on 13. This reduction is evident in part A in the end of m. 65, part B in the beginning of m. 67, and part C in the beginning of m. 68. The sequence continues to diminish one value at a time, and by m. 73 all three players are left with rolls.

[6.7] In **Example 15**, the palindromic structures from mm. 60–74 are diagrammed to illustrate their gradual diminution. All three performers initially realize structures based on sequences of 21 and 13, with varying degrees of diminution leading up to m. 74.(14) The most frequently used palindromic sequence ends on 13, particularly prominent in player A's part. This sequence is repeated four times in palindrome form over six measures from mm. 65–71. Upon examining the score, the reason that Xenakis chose to repeat this sequence becomes clear, which is that it corresponds with the number of thirty-second notes in a single measure of common time (see, for example, m. 65). In mm. 70–71 the performer is able to directly observe and experience the music's symmetrical design as the sequence ascends from 1 to 13 and then descends back to 1.

[6.8] The final second-order structure appears within the third part of the piece spanning mm. 80–116. Throughout this section, Xenakis instructs performers to use sticks for the *bord* notes and hands for the *basse* notes. The reason for this is technical, as using a drumstick allows for many more *bord* notes compared to *basse* notes.(15) For analytical purposes, the *basse* notes serve as a better anchor to conceptualize sequences presented by intervallic structures due to their relative scarcity. Focusing now on mm. 80–83 (**Example 16**), we see the sequence performed by player C is palindromic, with its axis of symmetry at the end of m. 81. The sequence from mm. 80–81 is 4, 4, 5, 4, 6, 4, 3, 5, 4, 5, 4. On the other side of the palindrome, from mm. 82–83, the sequence is read backwards towards the axis of symmetry: 4, 4, 5, 4, 6, 4, 3, 5, 4, 5, 3. The only difference between the two sequences is the final number. The near-perfect retrograde additionally accounts for timbral changes in both the *bord* and *basse* notes, which are marked in green in Example 16.

Analysis: Third-Order Structures

[7.1] As described in the typology given earlier, third-order structures are formed when complete sequences of intervallic structures combine to create a chiasmus that spans more than five measures. The complexity required to achieve exact symmetry in these large-scale structures makes it difficult to classify them as palindromic structures. To recognize third-order chiasmi, then, a secondary-order analysis is facilitated to calculate the initial numeric sequence, which is then combined and compared across multiple sequences.

[7.2] The first third-order chiasmus emerges in mm. 83–91. The source sequence for this structure first appears in mm. 83–84 (**Example 17**). As was the case for previous palindromic structures, this sequence is also based on calculating intervals using the *basse* timbres as reference. *Basse claquée* timbre marks the beginning of the sequence; this is followed by a pattern of *basse normale* and *basse étouffée* before the next *basse claquée* in m. 84. As the section develops, this rhythmic structure is either repeated in its entirety or slightly adjusted in the number of intervals between each *basse* timbre. An example of such similarity is found between player B's part in m. 83–84 and player A's in mm. 87–89 (Example 14). These two parts are identical in timbre and in intervallic sequences: 5, 4, 6, 4, 7, 4, 4, 5, 5, 5.

[7.3] Sequences from performer A (mm. 83–84) and performer B (87–89) can now be traced across the broader segment of mm. 83–91. An identical sequence appears for performer A from the end of m. 87 to m. 88. Two modified sequences are played by performer B from mm. 84–85 (**Example 18**) and by performer A from mm. 89–91.(16) I argue that these seemingly contrasting sequences in fact embody similar instances of the structure. Accounting for slight surface dissimilarities, the structure for these four sequences in total can be read as A, A′, A, A′. Texture may also aid in clarifying the parts of the chiasmus. In m. 83, performer B plays the sequence as a solo, whereas in mm. 84–86, the subsequent sequence is played alongside performer A and C as *tutti* (t). The opposite holds for mm. 87–88, where performer A plays a sequence within performer B and C's textures. Finally, performer A plays solo from mm. 89–91. When accounting for these textures, the structure then becomes: A, A^1t, At, and A^1.

[7.4] Notably absent from this account to this point is performer C's solo, situated in the middle of the chiasmus among four A sections in mm. 86–87. The intervallic structure presented in the solo differs slightly from performer B's initial sequence; here it is 5, 5, 6, 5, 7, 5, 4, 6, 5, 6. Accounting for this, the final form of the structure spanning mm. 83–91 becomes A, A′t, B, At, A′. Performer C's solo sequence thus serves the critically important function of linking the first large-scale chiastic

structure to the next. As it did in its first appearnce, the sequence takes the central portion of the bridging structure.

[7.5] A number of other sequences within this bridging structure spanning from mm. 91–96 present notable similarities. The sequence played by performer B in mm. 93–94 is identical to performer A's sequence in mm. 91–92 (**Example 19**). Additionally, in the sequence from mm. 93–95, performer A's *basse* notes feature an altered final note from the usual *basse étouffée* to *basse claquée*. This change creates a palindrome when considering the *basse* timbres, with the axis of symmetry at the barline between mm. 93–94.

[7.6] The final third-order structure, a quasi-chiasmus, starts from the tutti segment in m. 96. The methodology for calculating its sequences are the same as for previous third-order structures and are related to the *basse* timbre. The intervallic structures in this case, however, are more compressed compared to the previous chiasmus. The first sequence from mm. 96–97 is as follows: 4, 3, 5, 3, 6, 3, 3, 2, 2, and 5 (**Example 20**). This pattern repeats in player C's solo segment from mm. 98–99, which is repeated on the tutti from mm. 101–2. The second sequence follows a pattern of 3, 2, 4, 2, 5, 2, 2, 3, 3, 4. It first appears in mm. 97–98 and is then repeated in player A's solo in mm. 100–101, in player B's solo from mm. 102–3, and finally in the tutti segment in mm. 103–4 (**Example 21**). The large-scale structure that results is At, Bt, A, B, At, B, Bt. The solo passages are situated in the middle of this chiasmus (A, B) played by performers C, and A. It is important to note that while the intervallic structures remains similar between recurring patterns of A and B, their content in terms of the distribution of timbre varies between each structure. The structure can therefore be viewed as a chiasmus, since these intervallic structures embody similar numeric sequences, but differ in timbre.

[7.7] **Example 22** presents a summary formal diagram depicting the three third-order structures, with colors representing individual intervallic structures; similar sequences are tracked according to color. The diagram highlights the central and the surrounding parts of the chiasmus. The first structure fits well as a chiasmus, as the intervallic sequences between performer B and A are similar. In terms of texture, the tutti surrounding performer C's solo passage further contributes to the perception of a chiasmus. Admittedly, the final structure, on account of performer B's solo passage from mm. 102–3, adheres somewhat more loosely to the definition of a chiasmus. However, aside from this solo passage, the structure qualifies, with tutti sections encapsulating the two solo sequences. The bridging structure between the two third-order chiasmi is more difficult to categorize, but becomes clearer when observing the meta-structure that combines all three. Performer A's sequence, which features the palindromic *basse* timbre, sits at the center of the three structures. There are exactly eleven measures from the start of third-order structures in mm. 83–93, and another ten from mm. 95–105. This bridging segment marks the midpoint of the chiasmus formed by the combination of all three third-order structures.

Summary.

[8.1] The symmetrical structures discussed above are shown in **Example 23** as a diagram that places them in the context of the entire piece. These structures exemplify Xenakis's concept of gradual process through their construction and deconstruction over time. The first six structures are more primitive, presenting the material that will eventually evolve into multi-measure forms. The initial three are presented as solo passages given by performers A and B. The following three chiasmi in mm. 25–27 and 32 are realized through the collaboration of all three performers. Texturally, the symmetrical structures become more well defined as the piece progresses. In the first structure, symmetry is obscured within the randomized sequences of timbres. By the second structure, the music more explicitly displays the chiasmus through performer B's solo. The subsequent chiasmi in mm. 25–27 and m. 32 are the clearest yet. While m. 32 may seem somewhat less transparent, Xenakis intentionally differentiates this measure by eliminating *basse* notes.

[8.2] Upon reaching mm. 59–104, Xenakis introduces a stark contrast by implementing a new tempo (De Cock 2015). Previously, Xenakis's use of symmetry was mostly confined to a limited number of measures, but from this point onward that trend is broken. The palindromic section De Cock discusses spans twelve measures from mm. 60–72, followed by a smaller palindromic

structure from mm. 80–83; two chiastic structures spanning sixteen measures in total follow in mm. 83–91 and mm. 95–104. As observed in the diagram, such symmetric structures take up a significant portion of music and occur both in the second and third large-scale sections of the piece.

[8.3] *Okho's* final section, beginning at m. 117, introduces polyrhythmic gestures performed by a single percussionist. This, it should be stressed, is a whole new type of complexity. Percussionists familiar with works of Xenakis will notice the direct quote in m. 119, which replicates the intricate polyrhythmic structure of 5:3 found in the A movement of *Rebonds* (Xenakis 1989, 2). The right hand plays five equal notes, while the left hand plays the symmetrical pattern of two thirty-second notes, followed by a sixteenth-note triplet ending with another two thirty-second notes. Following this moment of symmetry, it becomes challenging to identify additional symmetrical structures until the end of the piece. In m. 121, the last structure is broken down into two separate arcs and is no longer able to support the same level of symmetry on its own.

Performance Semantics

[9.1] Fabrice Marandola (2012, 189) and Steven Schick (2013), renowned Xenakis experts, interpret silence versus rhythmic saturation in Xenakis's music as manifesting temporal dissonance versus stability. Gibson (2011, 81) further explores this duality, explaining that Xenakis's "concept of symmetry. . . [represents] the opposite of chaos, chance, or disorder."(17) Xenakis, himself, furthermore connected his aesthetics of saturation and silence to his youthful years in the Greek resistance. Resistance is literally coded into Xenakis's music, a music "filled with cadence. . . the slogans, cries punctuated by machine guns, the pounding feet of those who fled," while another "with long intervals of silence. . . and reverbera[tion] on and on through the town" (De Cock 2015).

[9.2] This same struggle between chaos and order resonates within *Okho*. Amidst the sea of Xenakis's stochastic timbral processes, one may perceive multiple attempts to establish stability through formal structure. These efforts are quite literally embodied in the piece's palindromic and chiastic organization. While the first two chiasmi are embedded within randomized textures, the first solo chiasmus overtly reveals the struggle, as the performer interprets sudden changes in timbre within a seemingly ordered structure. This contrast between chaos and clarity becomes more pronounced through changes of timbre and tempo—from the overwhelming pace of 120 bpm to the calm of 56 bpm—allowing the performer to calmly reorganize their progress and start anew.

[9.3] At the center of the piece, the well-crafted palindromic structure contains Fibonacci sequences. This section further animates the piece with thirty-second notes and a quickened tempo. What follows in m. 73, silenced and then the hushed rolls of the djembes, might at first appear anticlimactic. Yet, it is in this silence where the music signifies completion of the architectonic structure being assembled around the Fibonacci sequence. This section is, in fact, the center of the largest chiasmus, which is the piece itself. *Okho* consists of 138 measures, and the Fibonacci sequence occupies the center, between mm. 60–80. There are 60 measures from the beginning to this sequence, and another 58 measures from the sequence to the end of the piece.

[9.4] The third part of the piece marks the establishment and breakdown of order. Starting at m. 80, the piece continues to exhibit symmetrical structures, but beyond m. 104, the architecture begins to crumble. Even the previous chiastic structure is rendered unstable, as a solo passage is inserted in between the last At and Bt. (Without it, the section would display another chiasmus.) This effect is exacerbated by the sudden increase in tempo to 92 bpm and the thirty-second notes introduced in the middle of m. 104, which both serve to quicken the pace unexpectedly. The distributions of timbres in this section are stochastic in nature and arranged in a similar style to the chaos seen at the beginning.

[9.5] The final section depicts the last total breakdown to chaos. Here, the final symmetrical structures are once again hidden beneath the chaotic soundscape, until the last structure in m. 121. (A further symptom of chaos is the sudden change in texture from m. 117, which presents significant challenges for the performers attempting to execute timbres written in polyrhythms.) After two measures, Xenakis suspends time by unleashing a trio djembe version reminiscent of the "Chaos" presented in *Pleiades* from mm. 124–26 and mm. 130–32 (Marandola 2012, 189).(18)

Conclusion

[10.1] This article's proposed methodology for analysis centered on chiastic structures opens new windows into comprehending the structure and meaning of Xenakis's *Okho*. While the analysis builds on Gibson's theory, it does not require a deep understanding of the mathematics behind sieve sequences and their matrices, as outlined in Gibson 2011 (103–14). A further advantage of this approach is that it provides a more accessible tool for both theorists and performers. We have long known that rhythmic sieves play a critical role in understanding *Okho*; here, we may newly appreciate how chiastic structures resolve inconsistencies between Xenakis's mathematical models and the final version of his piece. Taken as a whole, perhaps the greatest benefit of this methodology is how it acknowledges and then, more importantly, aligns the composer's dual interests of mathematics and Classical literature.

[10.2] For performers, chiastic structures may serve more practically as a tool to help identify the sections that require more energy or emphasis. The complexity of Xenakis's works is such that it often overwhelms student and professional percussionists alike. However, analyzing these structures can help percussionists determine which parts should be played with precision, and which—in the terminology of Sharon Kanach (2010) and Ben Duinker (2021)—can be "negotiated."[(19)] In *Okho*, the chiastic structures reflect Xenakis's contrast between stochastic elements and ordered symmetry, which in turn can be loosely analogized to the performer's process of translating the manuscript into performance.[(20)]

[10.3] Moving beyond *Okho*, the method proposed here may be used to analyze other compositions by Xenakis for percussion.[(21)] My interests lie in two works whose titles directly reference classical literature: *Persephassa* and *Psappha*. Both works have been extensively analyzed through sieve theory, as by Besada, Barthel-Calvet, and Pagán Cánovas (2021) and in Gibson's 2011 analysis. Critically, however, they have not been examined with chiastic structures in mind. In basing the analytic method on intervallic structures, my approach yields structural insights that cannot be fully captured by sieve theory alone.

[10.4] Xenakis scholars have long recognized the connection between his compositions and Greek mythology. However, these connections have primarily been explored through the musicological and biographical perspectives of the composer. Which is to say: limited attention has been given to understanding Xenakis's compositional methodology as a Greek architect deeply influenced by the legacy of Classical antiquity. Future studies that fully integrate Xenakis's engagement with Greek poetry and mathematics—particularly as seen in his use of numerical patterning and chiastic structure in works like *Okho*—will no doubt deepen our understanding of Xenakis as a composer profoundly shaped by architectural thinking.

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Footnotes

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1. Nouritza Matossian (1986, 9) acknowledges Xenakis's multidisciplinary interests and pledges to enlighten equally "his architectural history as to his musical formation, to his theories as to his oeuvre, to his response to ancient Greek literature as to electronic technology." Another scholar interested in the intersection between Classical antiquity and Xenakis is Pierre Albert Castanet. Castanet's commentaries (2014, 14–35) reveal Xenakis's dramaturgical inspirations for several of his works featuring baritone, such as *Kassandra* (1987) and *Ais* (1980). The two works draw on Aeschylean tragedies and Homeric rhythms. Castanet's comments also reveal the depth of Xenakis's knowledge in ancient greek, reaching to differentiate Attic and Homeric Greek (*Odyssey*, *Illiad*, Homeric hymns) dialects when observing the lyrics of the two pieces.
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2. For more information, see Kanach, Sharon, and Iannis Xenakis 2001 and 2008, Gibson 2011, and Xenakis, Brown, and Rahn 1987 (16–63).
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3. Mentioned in Matossian 1986 (184), Exarchos 2008 (54–80) and 2011, and Gibson 2011 (81–114).
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4. Concerning full explanations on mathematical theories associated with sieves such as union, intersectionality, and complementarity, see Gibson (2011, 83–94) and Exarchos (2008, 54–80; 2011).
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5. Examination of Matossian 1986, Harley 2004, and Gibson 2011 publications reveal how Xenakis was fascinated by rhythmic sieves and their symmetry, especially in the few years leading up to *Okho* (1989) from *Idmen B* (1985). Gibson's cross-references between *Idmen B*, à *l'Île de Gorée* (1986) and Harley's comments of sieves in *Oophaa* (1989) are particularly illuminating. These compositions are not the first to incorporate sieves, however. Xenakis's first work using pitch as sieves is *Nomos Alpha* (1965), as described in Matossian 1986. The first known instance where Xenakis incorporated rhythm to sieves is in *Persephassa* (1969); this technique reappears in *Psappha* (1986).
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6. Xenakis introduces his stochastic processes in his first chapter of *Musiques Formelles* (*Formalized Music*, 1992). For example, his algorithm created for *Achorripsis* (23, 29, and 30), which embed elements of *poisson distribution* relevant to gas theory, stays consistent as a value is inputted, yet randomizes its output. The algorithm is later fully computerized through an IBM 7090 as seen in "Free Stochastic Music by Computer" (Chapter 5).
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7. Indicated in De Cock 2017 (48), Teodori 2012 (24), Rockwell 2015 (38), and Xenakis's notes embedded within the scores for *Persephassa* (1969), *Pleiades* (1979), and *Psappha* (1986).
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8. A prominent example is in *Aeneid IV* (Virgil), where Dido and Aeneas meet in the cave to proclaim their marriage. The original Latin text from the line 165—*speluncam Dido dux et Troianus eandem deveniunt* (Dido and the Trojan leader reach the very same cave)—contains a chiastic structure in ABB'A', where the object *speluncam* (cave) is declined as an accusative (object) in agreement with *eandem* (adjective), followed by the verb *deveniunt* (third person plural, "to arrive at"). This phrase syntactically envelopes Dido and Aeneas (*dux et Troianus*), providing a clever rhetorical mirroring of their physical and symbolic convergence within the cave. The marriage ceremony (166–68) and the prophetic messaging of their tragedy (170–71) are additionally structured as chiasmi, where the mythical depiction of the marriage and the proclamation of love in public are centered within. For more information, consult Fratantuono and Smith's (2022, 1–8, 17–20, 56–57, 320–34) translation and commentary.
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9. For the purpose of this paper, the term chiasmus predominantly applies in two contexts: in ancient Greco-Roman literature and in pediment artworks created to decorate temples. The rule prohibiting repeating parallel sections according to Corbett 1965 (438) should be scrutinized on a case-by-case basis, as smaller phrases and images may be exactly repeated in reverse.
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10. The translated version of this text is from Page DuBois 1978 (98).
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11. For more information about the exact Greek word structures and interpretation, see DuBois 1978 and Barkhuisen and Els 1983.
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12. I have deleted a transitory segment from the original structure constructed by Barkhuisen and Els 1983 for clarification. The core of the structure remains similar.

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13. Traditional djembe techniques call for tones and slaps to be open, which require a rebound. A closed slap is a non-traditional technique for djembe, but rather for Latin hand drums such as congas. The player strikes faster for slaps, and their hand stays on the drum for closed slaps. This in turn shortens and articulates the tone.
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14. There is an exception in performer A's sequence pattern in m. 67. The third sequence does not embed the pattern 8 when ascending from 1, 1, 2, 3. . . and skips directly to 13 from 5 (Xenakis 1989, 10).
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15. Percussionists can use their fingers to manipulate the velocity of the stick, which greatly increases the speed of their strokes. Measured strokes such as double or triple strokes are controlled using a combination of middle and ring fingers to ensure that the gesture does not exceed or fall short of the desired number of strokes.
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16. Changes for performer B's second sequence are easier to notice when observing the first sequence. Only the second term is raised by one from 4 to 5. It may be difficult to observe how performer A's sequence has been modified from performer B's initial sequence. For performer A's sequence, the eighth term has been removed, and the rest are increased by 1. Performer B: (5[+1], 4[+1], 6[+1], 4[+1], 7[+1], 4[+1], 4 [+1], ~~5~~, 5[+1], 5[+1]); Performer A: (6, 5, 7, 5, 8, 5, 5, 6, 6).
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17. The association between rhythmic saturation/chaos against ordered symmetry is, in fact, a thread running throughout the scholarship on Xenakis; it is regularly referenced by performers, theorists, and biographers alike. See Araya 2024 (186, 188), de la Torre 2024 (211), Zaplitny 1975 (87–88, 96). Readers may further observe the program notes for *Ensemble de Percussions de Strasbourg* for their April 12, 2022 performance (Fischer 2022).
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18. Marandola (2012, 189) defines "chaos" in *Pleiades* as an "abrupt change [taking] place, when all of a sudden two parallel voices break up into six separate voices, each evolving at its own pace." In the context of *Okho*, where there are three voices, each part plays a tuplet that is finely differentiated from other parts. Although not as extreme as *Pleiades* (in which each part is assigned a different tempo marking), the differentiated tuplets (5:8 with 5:7) blur any sense of pulse established since the beginning of the piece.
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19. In the preface of *Performing Xenakis* (2010), Kanach conceived the idea that performing Xenakis's works are part of a "negotiation" (x–xiii). The inspiration for Kanach is Steven Schick's comments on the challenges of performing the composer's corpus: "In Xenakis, there are truly and verifiably impossible passages, but they are positioned just barely out of reach." Kanach also reiterates that Xenakis's mathematical conceptions were loosely followed until the final version of the score, and thus argues that performers also deserve leniency to "depart from the written score" (Kanach 2010, xiii).
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20. The analysis furthermore considers Xenakis's slower tempo markings for symmetrical structures, which aid the performer in executing these sections more accurately.
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21. This method could also potentially be extended to works written for melodic instruments. Gibson's discussion of the superimposition of rhythmic and melodic material between *Persephassa* and *Antikthon* suggests that analyzing *Antikthon* through chiastic structures could yield promising results, as the two compositions are closely related.
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