

Encontros

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Singing with the Muses: new paths  
into ancient *Mousikē*

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'Though this be madness, yet there is method in 't.'  
(Shakespeare, *Hamlet*, Act 2.2)

## Resumo

Este artigo oferece uma visão geral de uma variedade de caminhos que podem ser seguidos para investigar o mundo rico e multifacetado da antiga 'arte das Musas', destacando o valor que diferentes perspectivas trazem para o estudo da *mousikē* antiga e seu desenvolvimento como disciplina. Em outras palavras, este artigo é uma peça metodológica no sentido etimológico do termo. É um logos escrito que ilustra diferentes *methodoi* – uma série de 'caminhos' (*hodoi*) que nos conduzem através (*meth'*) do mundo da música grega antiga e revelam aspectos diferentes, mas complementares, dessa complexa realidade.

Dado que a dimensão histórica dessas questões importantes foi discutida em outro lugar, este artigo explora a interação produtiva de diferentes dimensões através das lentes de minha própria jornada de pesquisa. Em particular, veremos como a interação de percepções oferecidas pela filosofia antiga, literatura e teoria musical, combinada com a evidência prática preservada pelos documentos musicais gregos e pela cultura material, mostra que precisamos desenvolver uma abordagem flexível e multifacetada para o estudo da antiga *Mousikē* para tentar recapturar algumas de suas características definidoras. As seções finais deste artigo incluem uma série de estudos de caso que mostram como novas ferramentas desenvolvidas na área de Humanidades Digitais têm grande potencial para o estudo da música antiga. Alguns desses materiais, incluindo performances modernas de partituras musicais antigas, bem como reconstruções 3D de instrumentos antigos, como os aulos do Louvre, são exibidos em um novo site dedicado, [eMousike.com](http://eMousike.com).

Palavras-chave: Música Grega Antiga, Documentos musicais gregos, Aulos do Louvre, Modelagem 3D, Humanidades Digitais.

## Abstract

*This article offers an overview of a variety of paths that can be followed to investigate the rich and multifaceted world of the ancient ‘art of the Muses’, highlighting the value that different perspectives bring to the study of ancient mousikē and its development as a discipline. In other words, this article is a methodological piece in the etymological sense of the term. It is a written logos that illustrates different methodoi—a number of ‘paths’ (hodoi) that lead us through (meth’) the world of ancient Greek music and reveal different, but complementary, aspects of this complex reality.*

*Given that the historical dimension of these important issues has been discussed elsewhere, this article explores the productive interplay of different dimensions through the lens of my own research journey. In particular, we shall see how the interplay of insights offered by ancient philosophy, literature and musical theory, combined with the practical evidence preserved by the Greek musical documents and material culture, shows that we need to develop a flexible and multi-faceted approach to the study of ancient Mousikē in order to try to recapture some of its defining features. The final sections of this article include a number of case studies that show how new tools developed in the area of Digital Humanities have great potential for the study of ancient music. Some of these materials, including modern performances of ancient musical scores as well as 3D reconstructions of ancient instruments such as the Louvre aulos, are showcased on a new dedicated website, [eMousike.com](http://eMousike.com).*

*Keywords: Ancient Greek Music, Greek musical documents, Louvre aulos, 3D modelling, Digital Humanities.*

**T**his article is a methodological piece in the etymological sense of the term: a written *logos*<sup>1</sup> that illustrates different *methodoi*—a number of ‘paths’ (*hodoi*) that lead us through (*meth’*) the world of ancient Greek music and reveal different, but complementary, aspects of this complex reality. In other words, this article offers an overview of a variety of paths that can be followed to investigate the rich and multifaceted world of the ancient ‘art of the Muses’, highlighting the value that different perspectives bring to the study of ancient *mousikē* and its development as a discipline, through the lens of my own research journey.

The study of ancient Greek music has developed rapidly over the course of the last 50 years, building upon seminal contributions made by Andrew Barker, Martin West and Egert Pöhlmann and drawing on a steadily increasing number of other disciplines.<sup>2</sup> The impressive development of this field as a whole and its historical implications have recently been discussed elsewhere.<sup>3</sup> In this article I shall therefore illustrate the significance and impact of different approaches to the study of ancient music by summarising the main stages of my research journey to date. It is my hope that this personal account will offer some helpful insights to students who are approaching this subject for the first time as well as scholars who are developing their own research projects.

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1 This essay originated as the opening lecture for the Second Meeting of the Grupo Brasileiro de Estudos da Música Greco-Romana e suas Ressonâncias (October 2022, Federal University of Paraná, Curitiba, Brazil). I am grateful to Roosevelt Rocha for his kind invitation, and the audience for their helpful questions and feedback.

2 See esp. Barker 1984 and 1989, West 1992, and *DAGM* (Pöhlmann-West 2001).

3 Lynch-Rocconi 2020, pp. 1–9, with Levitan 2023.

# 1. Ancient Greek Music: the Art of the Muses

'Let us begin to *sing* from the Muses of Helicon...' (Hes. *Th.* 1.1);  
 'Sing, o Goddess, the wrath of Achilles son of Peleus...' (Hom. *Il.* 1.1).

These iconic beginnings of the epic poems that set the foundations of Greek literature as we know it show how the ancient 'art of the Muses' was far more than simple 'poetry', intended as 'speech having metre'.<sup>4</sup> Ancient Greek poetry was, in contrast, fundamentally musical in nature. Ancient Greek poems were in fact fully fledged songs performed to the accompaniment of musical instruments; an indissoluble blend of melody, rhythm, and words<sup>5</sup> that originated from the Muses and celebrated them first and foremost—the mythical daughters of Memory and Zeus, and their power to inspire the creation of beautiful compositions that preserve knowledge of the past and grant imperishable glory to human beings and their deeds (Hes. *Op.* 1.1).

This traditional mindset was still alive in Imperial times and is at the heart of a short song attributed to the Cretan musician Mesomedes, a piece that survives in musical notation to this day (DAGM 24). This brief invocation of the Muse, transcribed in Figure 1, echoes the opening lines of the great epic poems and asks for literal inspiration: a creative musical breath sent by the Goddess to stir the imagination of human composers, making their minds and voices quiver (*doneitō*) like an aulos reed (*donax*).

The image shows two staves of musical notation in 12/8 time. The first staff has a treble clef and a key signature of one sharp (F#). The melody consists of quarter and eighth notes. Below the staff are Greek letters representing notes: C, Z, Z, Φ, Φ, Φ, C, C, I, Φ, M, M. Underneath these are the Greek lyrics: Ἄ - ει - δε Μοῦ - σα μοι φί - λη, μολ - πῆς δ' ἐ - μῆς κατ - ἀρχ - ου. The second staff also has a treble clef and one sharp. The melody continues with quarter and eighth notes. Below the staff are Greek letters: Z, Z, Z, E, Z, N, N, I, I, M, Z, N, I, Φ, C, P, M, Φ, C. Underneath are the Greek lyrics: ἄν - ρη δὲ σῶν ἀπ' ἀλ - σέ - ων ἐ - μάς φρέ - νας δο - νεί - τω.

Sing to me, beloved Muse,  
 and start my tuneful strain;  
 may a breeze from your sacred groves  
 now come and rouse my wits.

*Áeide Moúsa moi philé,  
 molpés d'emés katárchou;  
 aúrē de sôn ap' alséōn  
 emàs phrénas doneitō.*

Figure 1: Modern transcription of the Invocation of the Muse (DAGM 24), with the corresponding Greek notes and lyrics, and an English translation of the text.

4 Gorgias *Hel.* 11: τὴν ποιήσιν ἅπασαν καὶ νομίζω καὶ ὀνομάζω λόγον ἔχοντα μέτρον.

5 Pl. *Resp.* 3.398c: 'melody is made of three components: speech as well as mode and rhythm (τὸ μέλος ἐκ τριῶν ἐστὶν συγκείμενον, λόγου τε καὶ ἁρμονίας καὶ ῥυθμοῦ).'

Besides witnessing to the continuity of a key cultural model, this short piece reflects the foundational role that Greek music had in the Roman world—a relationship enshrined in the word *musica* (sc. *ars*), the Latin translation of the Greek word *mousikē* (sc. *technē*).<sup>6</sup> In this connection, it is significant that *mousikē* was one of the first, if not the very first, areas of Greek culture to be conceptualised as a unitary, self-standing ‘craft’ (*technē*),<sup>6</sup> governed by a system of principles, premises and practices. This extraordinary theoretical breakthrough stemmed from the powerful combination of emotional, aesthetic and cognitive elements that defined the essence of ancient *mousikē*, and cemented the central role it played in ancient culture. But Greek musical theory and practice continued to have a crucial impact well beyond antiquity, of course. In many ways, the Greeks defined the grammar, and essence, of our own musical thinking: after all, it is to the Greeks that we owe most of the words that we still use to talk about music, such as harmony, rhythm, melody, metre, tone, and so on.

Yet, differently from what most people expect, ancient Greek *mousikē* did not embrace only music in the modern sense of the word. This complex notion included music as well as many other ‘products’ of the divine art of the Muses, such as poetry, prose, rhetoric, dance and drama.

A seamless blend of these aesthetic expressions combined with instrumental and vocal music gave rise to a variety of artistic performances that permeated the lives of Graeco-Roman communities at all levels—from small-scale recitals at private symposia to simple choral songs and instrumental pieces that played a central role in educational settings as well Orphic mystery cults, up to complex multimedia productions such as tragedies and comedies, which involved professional musicians as well as ordinary citizens and occurred in the context of all-important public events.

For this reason, the Greek cultural discourse on music did not focus exclusively on performative aspects and rather involved a complex repertoire of cultural values that were expressed by means of, and associated with, specific musical languages, preferences and styles.

Hence *mousikē* became the subject of heated cultural debates that were by no means limited to a purely aesthetic dimension but concerned the whole realm of social experience and culture, including not only ethical, political, and educational issues, but also psychological, medical and religious ones. Expressions such as ‘lyreless’ or ‘chorusless’ were therefore employed as self-evident symbols of desperate sadness, fitting for funerary dirges and the crushing realities of war.<sup>7</sup> Similarly, not knowing how to play the lyre, or how to sing and dance in a chorus, revealed a lack of the most basic kind of education.<sup>8</sup>

This rich and complex cultural background shows, I hope, the reasons why we need to adopt a multidisciplinary, as it were ‘polyphonic’, methodology in

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6 E.g. Eur. *IT* 143–7; *Hel.* 185–91; Soph. *OC* 1220–23.

7 Ar. *Vesp.* 959–9; Pl. *Leg.* 654a–b.

8 I.e. what lets us ‘observe’ (*skopein*) ‘beautiful forms’ (*kala eidē*).

order to try to recapture some of the defining aspects of the complex world of ancient *mousikē*. In other words, I believe that we need to look at ancient music through a sort of theoretical ‘kaleidoscope’ in the etymological sense of the word,<sup>9</sup> developing a multifaceted and interdisciplinary paradigm that enables us to observe constantly changing, but deeply related, patterns of beautiful musical shapes and forms—theoretical as well as practical, imagined as well as experienced in performance.

In keeping with this belief, over the last ten years or so, I have developed a new approach to the study of *mousikē* that combines practical and theoretical evidence concerning ancient harmonics, rhythmic and notation with vital cultural insights offered by literary and philosophical sources. The following sections of this article will show how my research journey followed many different ‘paths’ into the realm of the Muses, and gradually revealed different aspects of their beautiful world. I hope you will enjoy the ride.

## 2. The origin of the journey: Plato and *mousikē*

It all began with Plato—a rather paradoxical starting point, if one is to believe the bad press he gets in academic circles. Plato’s alleged ignorance, or lack of interest, in musical matters has been a common trope in modern scholarship, a trend that is in many ways rooted in Nietzsche’s vitriolic characterisation of Plato as the ‘greatest enemy of art that Europe has ever produced’.<sup>10</sup> But this strongly worded stance has relatively little to do with Plato, and a lot more to do with Nietzsche’s own philosophical struggles.<sup>11</sup> Likewise scholarly arguments that are, more or less consciously, built upon this foundation do not engage with ancient evidence on its own terms and are often based on superficial judgements or preconceptions.

As recently as 2015, for instance, Robert Wallace categorically dismissed musical technicalities as ‘trifles’ allegedly ‘unworthy of a philosopher’ such as Plato.<sup>12</sup> This scathing characterisation is, however, hardly justified, not least because Plato’s Socrates famously described philosophy as ‘the greatest kind of music’ (*Phaedo* 61a). A passage of the *Philebus* likewise describes music as a necessary component of *any* human life worth the name<sup>13</sup>—not exactly a trifling matter.

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9 I.e. what lets us ‘observe’ (*skopein*) ‘beautiful forms’ (*kala eidē*).

10 Nietzsche, F. (1887) *Genealogy of morals* 3.25

11 Cf. Nehamas 1985, 136–137.

12 Wallace 2015, xxii, misrepresenting Koster 1945, 164, who described this position as a possibility among others.

13 *Philebus* 62c: Socrates: ‘And shall we also add music, which we have just said to be full of guesswork and imitation, and lacking in purity?’ Protarchus: ‘Absolutely—it seems necessary to me, if our life is to be a life of any kind’. Earlier on in this passage, the state of a man who is an expert in ‘purely’ philosophical and ‘divine’ sciences but is ignorant of our human sphere is described as a ‘ridiculous condition’ (*Philebus* 62b: γελόϊαν διάθεσιν).

In keeping with this, Plato's dialogues offer a number of thought-provoking discussions of the ethical, political, educational and psychological importance that music had for the Greeks. This is especially true in the case of the *Republic* and the *Laws*, works which describe in detail the set-up of two ideal constitutions and the lifestyle of their citizens. Among other things, musical education is described as 'the most important' and 'supreme' (*kyriōtatē*)<sup>14</sup> kind of early training to be received by the future Guardians of the ideal constitution. The scientific study of harmonics plays an equally central role in their advanced philosophical formation, where it is presented as nothing less than a 'divine task' (*daimonion pragma*).<sup>15</sup>

But Plato's interest in musical questions was by no means limited to its ethical, political and psychological implications. Key passages of the *Republic* and *Timaeus* that describe structure of the universe are in fact based upon musical notions—complex but familiar conceptual models that Plato shared with his readers. For this reason, as I have argued in detail elsewhere, musical models are not employed as 'mere metaphors' in Plato's dialogues, i.e. purely symbolic or cosmetic representations of his innovative ideas. In contrast, Plato employs musical concepts as truly mimetic likenesses—aesthetic as well as conceptual models that allowed him to illustrate the dynamic and at times conflictual, but nevertheless fundamentally harmonious organisation of the *kōsmos* by virtue of the 'earthly' notions and practices they evoked in the mind of his readers, and not in spite of them.<sup>16</sup>

In a number of articles, I have offered technically informed examinations of many of these passages, casting light on Plato's pervasive and purposeful use of musical theory, concepts and practices. These publications show how Plato was acutely aware of the technical implications of his musical choices and actively exploited them to reinforce central points of his philosophical projects, including the definition of temperance (*sōphrosynē*) and justice (*dikaïosynē*) offered in *Republic* 4, and the harmonic organisation of the 'Soul of the Whole' discussed in the *Timaeus*.<sup>17</sup>

Likewise, a book currently in preparation<sup>18</sup> shows that Plato's characterisation of the emotional effects of the Classical modes (*harmoníai*) is far from being a figment of his philosophical imagination. On the contrary, Plato's selection of the modes to be employed in the early education of the Guardians is deeply rooted in the musical traditions and practices that shaped the core of Classical Greek culture, and takes into account the technical features of different modes

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14 *Resp.* 3.401d4-e1.

15 *Resp.* 7.531c.

16 This methodological principle is discussed in detail in Lynch 2020a, 113–115.

17 See Lynch 2017 on Plato's definition of temperance as a choir singing in octaves; and Lynch 2020a on justice in the *Republic*

18 Lynch (forthcoming 1).



as well as their traditional associations with particular performance contexts and musical instruments.<sup>19</sup>

### 3. Reconstructing the Revolution of the New Music I: from theatres to theory

This brief summary of my work on Plato and music shows, I hope, that reconstructing the scales and tunings used in ancient Greek music from a practical as well as a theoretical point of view is vital in order to recapture, and bring back to life, key aspects of ancient culture, literature and philosophy.<sup>20</sup> Reconstructing the sounds of ancient Greek music, in other words, brings us a step closer to recapturing the significance and implications of the musical ‘mental pictures’ that shaped a number of key philosophical ideas such as the harmony of the soul, as well as its ethical, educational and political implications.

For this reason, since the very beginning of my research journey I have explored the technical side of the world of ancient Greek music in various ways. Since 2017, I have however focused more closely on the relationship between ancient modes (*harmoniai*) and notation keys (*tonoi*), and the central role they played in the so-called Revolution of the New Music.

This important chapter in the history of Classical Greek music was the topic of a conference I organised in Oxford, the 10<sup>th</sup> Moisa Meeting. On this occasion, I presented a paper that reconstructed the controversial modulation system introduced by late Classical performers such as Phrynis, Timotheus and Philoxenus, and their relationship to the two main families of Greek instruments: double pipes (*auloi*)<sup>21</sup> and professional lyres (*kitharai*). This material is now available in an article that was published in 2018, which focusses on a passage of Pherocrates’ *Chiron* that makes fun of the harmonic innovations introduced by a number of

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19 A preliminary discussion of these issues is offered in Lynch 2016. Some details of this analysis will be substantially refined in Lynch forthcoming 1—for instance, the transcriptions I offered in 2016 are a major third higher than they should be. Updated transcriptions are however provided in Lynch 2020b.

20 Another element was, of course, equally crucial in determining the character of ancient Greek compositions: musical rhythm (*rhythmos*), the dynamic ‘shape’ given to the flow of the singing voice and dancing bodies. A full discussion of these issues would go beyond the limits of this article, so readers who are interested in finding out more about this vital aspect of ancient musical theory and practice can have a look at Lynch 2020c and Lynch 2022c, together with West 1992, esp. 129–159 and 242–5.

21 It is important to note that Greek *auloi* and Roman *tibiae* were not ‘flutes’, a mistaken translation that is still very common. As discussed below, *auloi/tibiae* were played in pairs and were equipped with double reeds (*aulētikoí kalamoí* or *donakes*). These instruments were therefore similar—but not identical—to modern oboes. Greek flutes (*plagiauloi*), in contrast, were played individually and without reeds, just like modern flutes.

New Musicians.<sup>22</sup> This passage is significantly preserved in the Pseudo-Plutarchan treatise *On Music*, and contains a number of clear references to technical aspects of the tunings employed by these avantgarde musicians. In keeping with this, the article shows how the extant evidence about ancient harmonic theory and practice allows us to reconstruct in some detail the increasingly daring modulations that Pherecrates ascribes to different late Classical musicians.

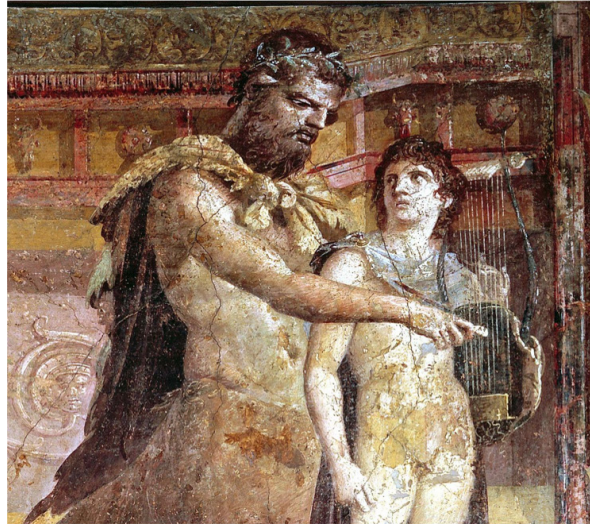


Figure 2 (on the left): The Megara auloi, 3rd century BC—Megara Archaeological Museum Δ1965α–β and Δ1964α–β (photograph courtesy of Chrēstos Terzēs). Figure 3 (on the right): detail of a Herculaneum fresco (National Archaeological Museum of Naples, inv. nr. 9109, [Public domain](#)) that portrays Chiron teaching Achilles to play a many-stringed lyre.

In particular, this article combines insights offered by comic and lyric poetry with technical evidence ranging from Aristoxenus to Ptolemy and Aristides Quintilianus, and shows how late Classical professional singers could produce up to seven different modes on one and the same kithara without interrupting their performance to retune it.

This ‘many-stringed revolution’ overturned the traditional model of the seven-stringed lyre and mimicked the legendary harmonic flexibility of the aulos. A star Classical aulos player, Pronomus of Thebes, was in fact remembered as the first to have been able to play the three basic *harmoniai*—Dorian, Phrygian and Lydian—on one and the same instrument.<sup>23</sup> As noted by Dionysius of Halicarnassus, these modulations formed the core of the new harmonic system that Timotheus and Philoxenus employed in composing late classical dithyrambos.<sup>24</sup>

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22 Lynch 2018. This article sadly contains some pretty horrible typos, which are indicative of my state of exhaustion at the time but fortunately do not affect the reconstruction offered there.

23 Paus. 9.12.5, Ath. 14.631e.

24 Dion. Hal. *Comp.* §19, 19.85.18–86.7 Usener, translated in Lynch 2018, 293.

As shown in Figure 4 below, the twelve-stringed tuning that Pherecrates ascribes to Melanippides reproduced the same modulation system on string instruments, enabling kitharodes to perform long, highly mimetic songs that featured intricate but seamless harmonic modulations.

Among other things, the article offers new hypothesis concerning the nature of an innovative gadget called ‘twister’ (*strobilos*) that Pherecrates ascribes to Phrynis. In the article, I argued that this gadget significantly expanded the number of tunings that could be played on a professional lyre as it allowed Phrynis to produce a special bending (*kampē*) of a semitone, which ‘coloured’ the central note of the Classical Dorian octave and introduced the ‘chromatic’ note *f#* into the diatonic realm of Classical *kithara* tunings. This chromatic expansion made it possible for Phrynis to combine five different *harmoniai* in one and the same twelve-string tuning: Dorian, Phrygian, Lydian, as well as lastian and ‘Loose Lydian’. Thanks to a subtle modification of this gadget, Timotheus further expanded the harmonic palette of his twelve-string *kithara* and added the lamenting *aulos*-mode par excellence, the Mixolydian, alongside the Dorian as well as the modes employed by Phrynis. In so doing, Timotheus introduced into kitharodic songs the perfect ‘blend of magnificence and *pathos*’ that was typical of tragic *aulos* music.<sup>25</sup>

Philoxenus made this system even more complex by adding an extra string set a tone above the upper boundary of the Classical central octave which corresponded to the Dorian key (c–c’).

As shown in Figure 4, this extra string inaugurated the so-called ‘hyperbolic’ tetrachord, and the resulting 13-string tuning corresponds to the 13-step arrangement that is at the heart of Aristoxenian harmonic theory.<sup>26</sup>

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25 Cf. Aristox. fr. 81 Wehrli (ap. Ps-Plut. DeMus. 1136d): tragedians ‘took the Mixolydian *harmonia* and joined it together (συζεῦξαι) with the Dorian, because the latter produces magnificence and dignity and the former extreme passions; and tragedy is a mixture of these’.

26 Cf. Lynch 2022a, Appendix 1.

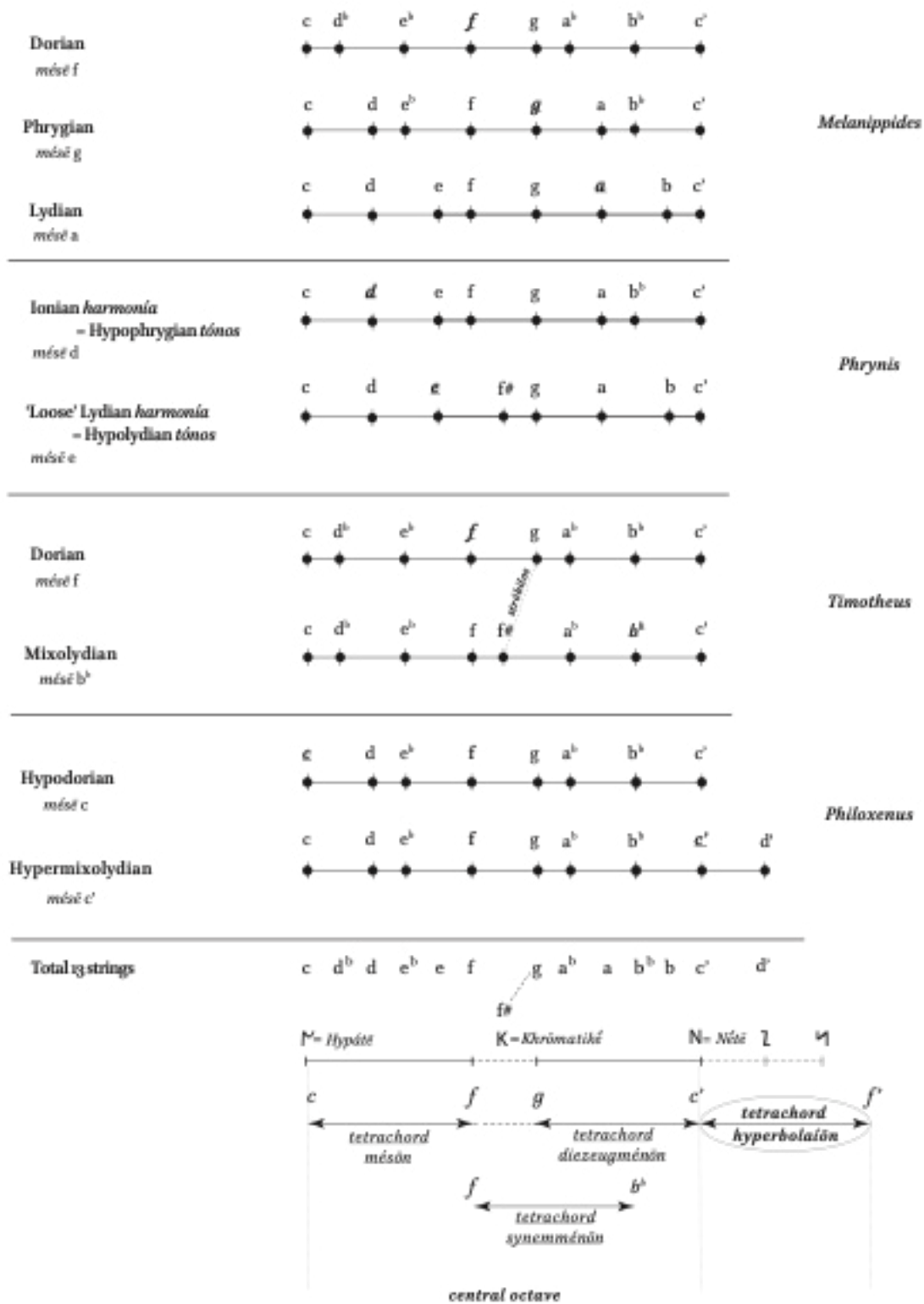


Figure 4: A reconstruction of the 'revolutionary' modulations of the New Music mocked in Pher. Chiron fr. 155 K.-A. (ca 410 BC)—Lynch 2018.

### 3. Reconstructing the Revolution of the New Music II: Classical harmonic theory and the Greek musical documents

The reconstruction of the modulation system of the New Music that I presented in 2017/18 worked very well on a theoretical as well as technical and literary level. But could it help us better understand the practical evidence offered by the extant musical documents? This is the main question that drove the second phase of this research strand, which I developed from 2020 to 2022.

In order to tackle this question, I had to find a way to explore systematically the evidence preserved by the Greek musical documents. I have therefore developed a new database called *dDAGM* that collects the musical notes attested in the standard edition of the Greek musical fragments (*DAGM*), for a total of over 3,500 notes. This simple tool makes it possible to analyse the standard record of ancient Greek musical scores on the basis of a variety of criteria, such as Hellenistic vs Imperial documents, instrumental vs vocal notes, and their harmonic organisation into groups of related Dorian, Phrygian and Lydian notation keys (*tonoi*).

As I have shown in two substantial articles published in 2022,<sup>27</sup> the reconstruction outlined in Lynch 2018 is fully supported by the evidence of the Classical and Hellenistic musical documents, and casts a new light onto the development of the Classical harmonic system. In particular, the first of these articles shows that 100% of the notes that are attested in the Classical and Hellenistic documents fall within the range of the Dorian Perfect system ( $F_2-F_4$ , Figure 5), in full accordance with technical evidence as well as literary and philosophical testimonies.

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27 Lynch 2022a and Lynch 2022b.

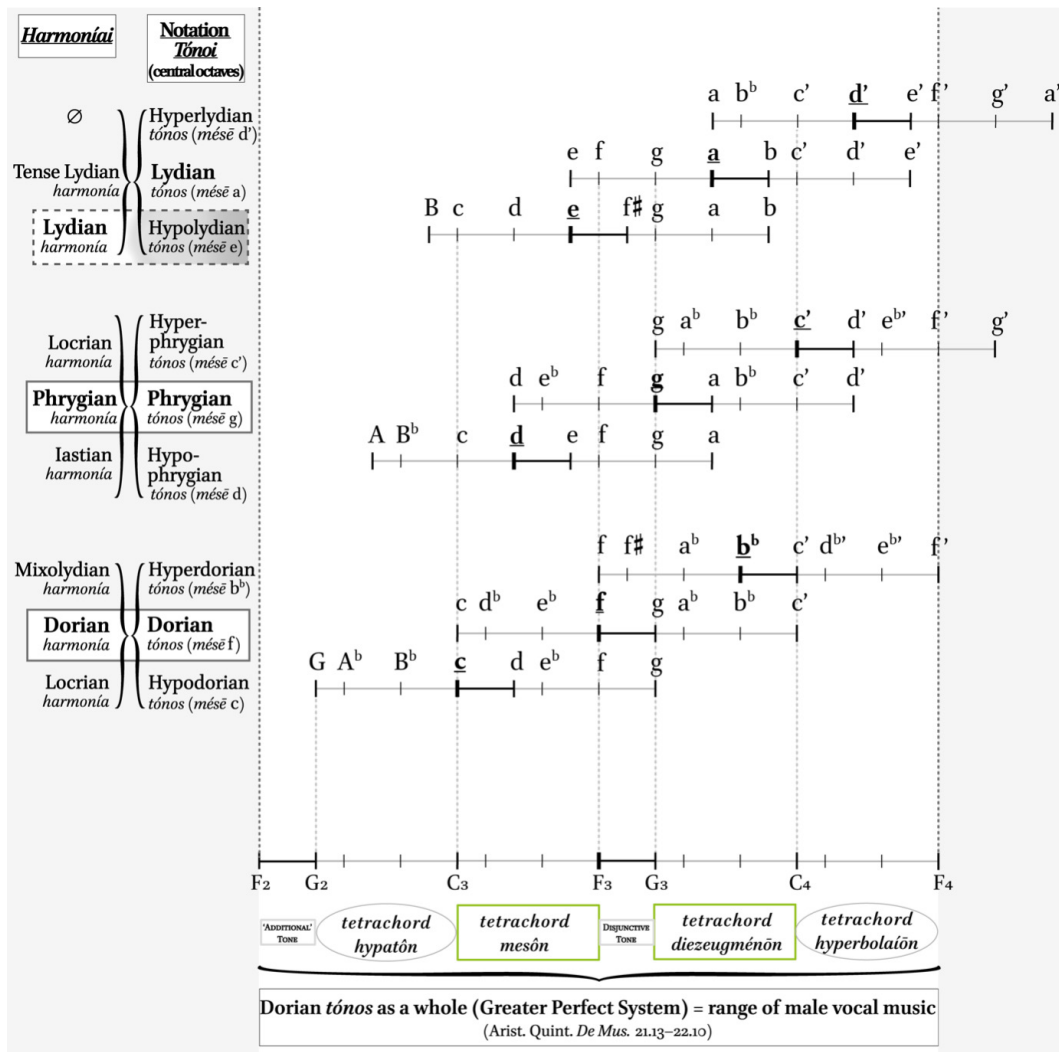


Figure 5: The Dorian Perfect System, the Dorian, Phrygian and Lydian notation *tónoi* (central octaves, diatonic variety *exempli gratia*), and the corresponding traditional *harmoníai*. This scale system accounts for 100% of the notes attested in Classical and Hellenistic documents (Lynch 2022a).

Secondly, Lynch 2022a showed that the intermediate notes (*mesai*) of the defining modes of Classical Greek music—Dorian, Phrygian and Lydian—are the most frequent notes employed in the relative families of notation keys used in Classical and Hellenistic scores. This feature is once again consistent with contemporary theoretical sources.<sup>28</sup>

As shown in Figure 6, Dorian *mesē* (F3) is the most frequent note in Classical and Hellenistic documents written in Dorian notation keys. In keeping with this, 99% of Dorian notes fall within the central Dorian octave C<sub>3</sub>-C<sub>4</sub>.

28 Esp. Ps.-Arist. *Prob.* 19.20, quoted below.



### Classical/Hellenistic notes written in Dorian Vocal keys

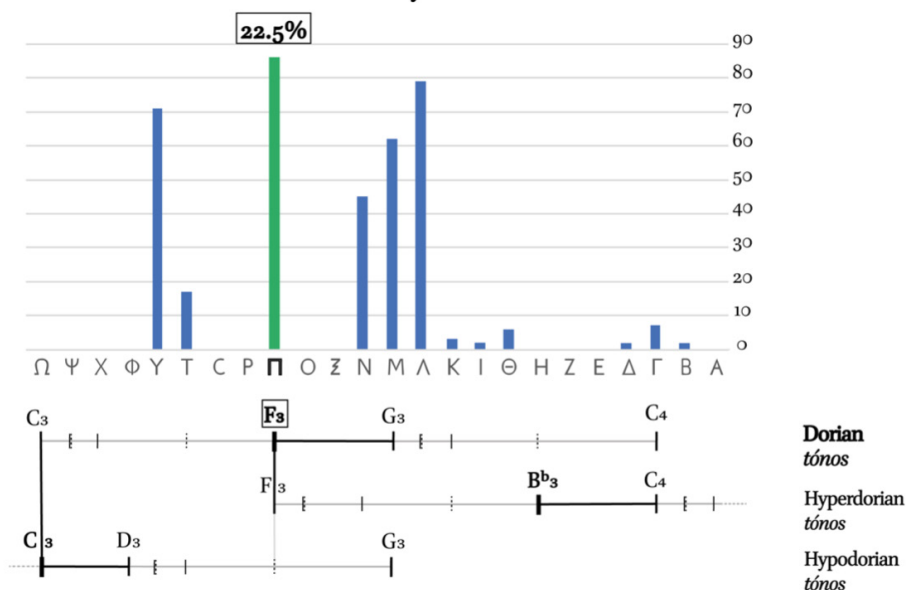
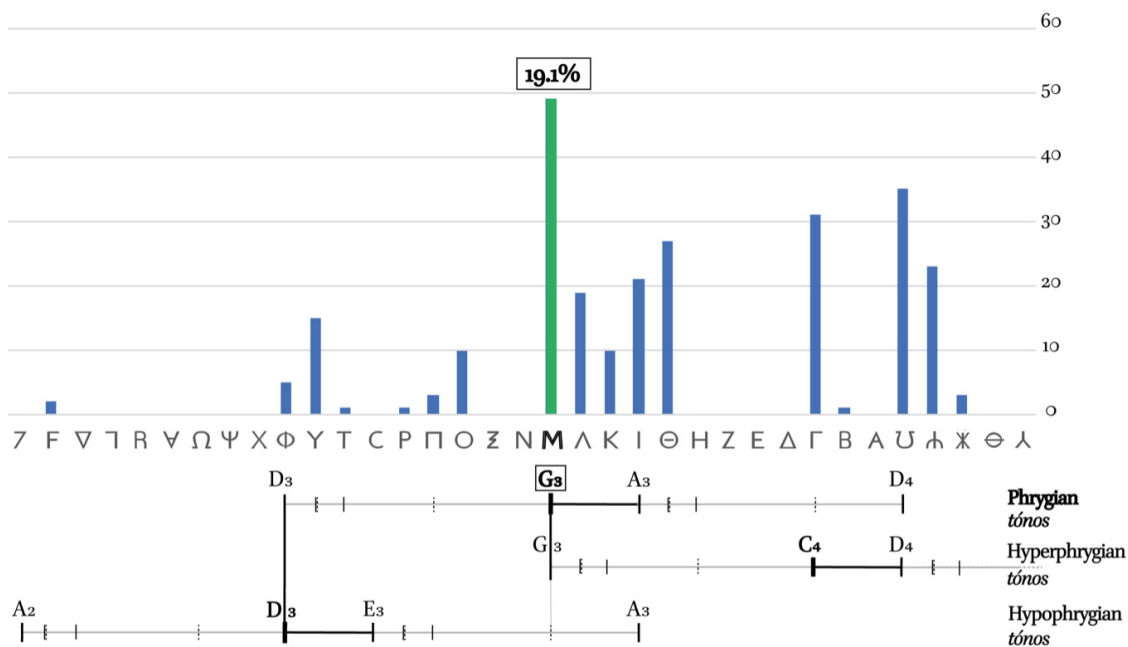


Figure 6: Dorian notes attested in Classical and Hellenistic documents and the relative notation *tonoi* (Lynch 2022a)

Likewise, Phrygian *mesē* G3 is the most frequent note attested in Classical and Hellenistic documents written in Phrygian notation keys, and 89% of Phrygian notes fall within the central Phrygian octave D<sub>3</sub>–D<sub>4</sub> (Figure 7).

### Classical/Hellenistic notes written in Phrygian Vocal keys









... πάντα γὰρ τὰ χρηστὰ μέλη πολλάκις τῇ μέσῃ χρῆται, καὶ πάντες οἱ ἀγαθοὶ ποιηταὶ πυκνὰ πρὸς τὴν μέσην ἀπαντῶσι, κὰν ἀπέλθωσι, ταχὺ ἐπανερχονται, πρὸς δὲ ἄλλην οὕτως οὐδεμίαν. καθάπερ ἐκ τῶν λόγων ἐνίων ἐξαιρεθέντων συνδέσμων οὐκ ἔστιν ὁ λόγος Ἑλληνικός, οἷον τὸ τέ καὶ τὸ καί, ἔνιοι δὲ οὐθέν λυποῦσι διὰ τὸ τοῖς μὲν ἀναγκαῖον εἶναι χρῆσθαι πολλάκις, εἰ ἔσται λόγος, τοῖς δὲ μή, οὕτω καὶ τῶν φθόγγων ἢ μέση ὥσπερ σύνδεσμός ἐστι, καὶ μάλιστα τῶν καλῶν, διὰ τὸ πλειστάκις ἐνυπάρχειν τὸν φθόγγον αὐτῆς.

(Ps.-Arist. *Probl.* 19.20)

... for all effective melodies use *mesē* a lot, and all good composers come upon it often; and when they move away from *mesē*, they come back to it quickly, whereas they do not behave in this way with any other note. Just as a Greek sentence would not exist if someone took away some conjunctions such as *te* and *kai*, whilst others would not be missed, as some must necessarily be used often to produce a sentence whereas others not so much—in the same way *mesē* is, as it were, a conjunction (*syndesmos*) among notes, and especially between beautiful ones, because this note is very often the origin of the others.

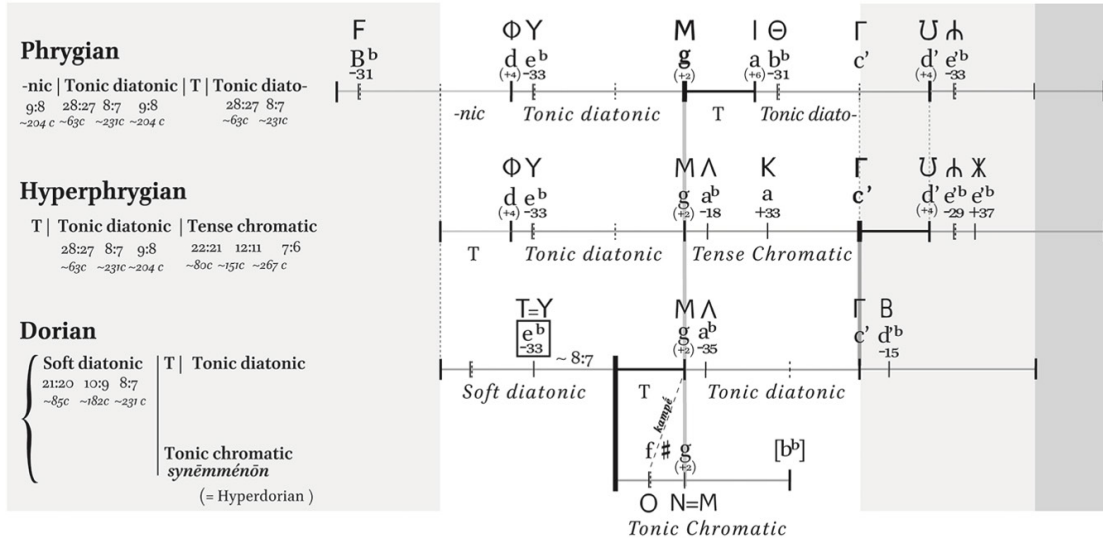
The second article of this series, Lynch 2022b, completes the picture by discussing in detail two musical documents that illustrate the modulation system of the New Music: the Ashmolean Papyri (DAGM 5–6) and Athenaeus' *Paeon* (DAGM 20).<sup>32</sup> These case studies include new modern transcriptions of these documents and show that the seemingly 'exharmonic' notes employed in these pieces correspond to the chromatic 'bends' (*kampai*) first identified in Lynch 2018. These 'bends' distorted the central pillars of the noble Dorian *harmonia*, introducing the chromatic note *f#* into the Classical harmonic system (Figure 10). This addition turned the Dorian mode into its polar opposite: the Mixolydian *harmonia*, the emotional and lamenting mode par excellence.

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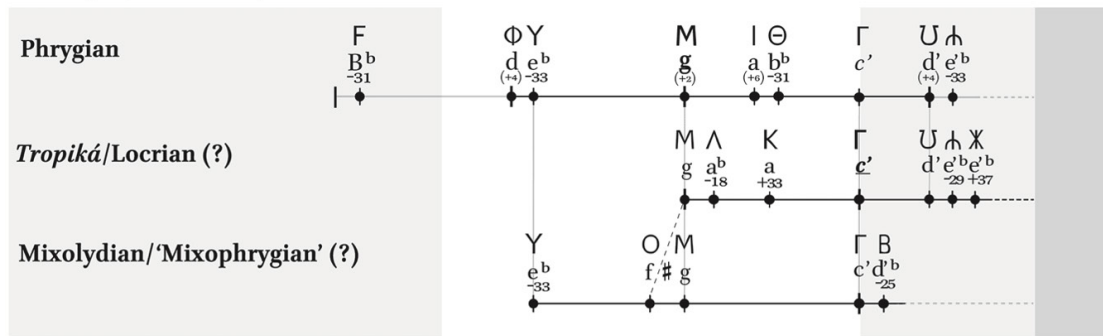
32 The full video recording of a recent performance of Athenaeus' *Paeon* that took place at the Ashmolean Museum, Oxford, is available on <https://www.emousike.com/athenaeuspaeon>.

## Harmonic structure of Athenaeus' *Paeon* (DAGM 20)

### • Notation Keys (*tónoi*)



### • Tunings (*harmoníai*)



### Cf. *Aristides' auletic harmoníai*

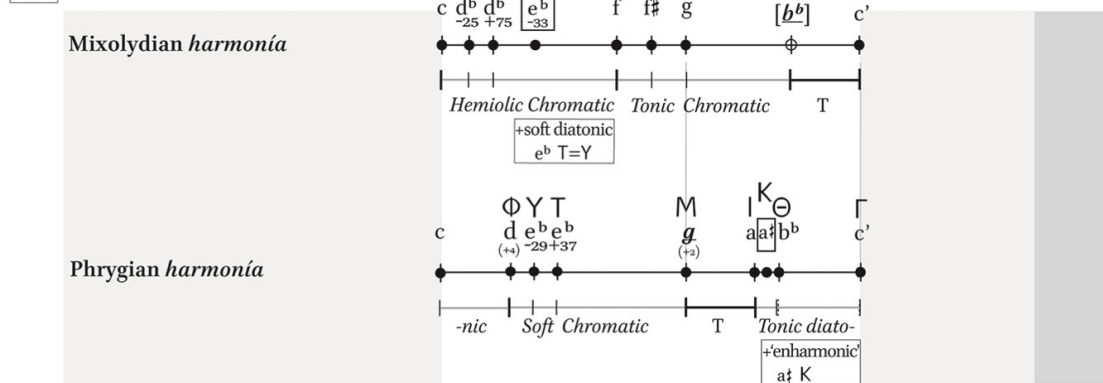


Figure 10: Notation keys and tunings employed in Athenaeus' *Paeon* (DAGM 20); Aristides Quintilianus' aulos-based *harmoníai* (Lynch 2022b)

Γ Ψ Η Ψ [Γ] Κ  
 ["Ην] κλυ-τά με-γα-λό-πο-λις Ἄθ-θίς, εὐ - χαι - εἶ - σι

Λ Μ Ο Κ Λ Κ Γ Ψ Η Ψ  
 φερ - ό - πλοι - ο ναί - ου - σα Τρι - τω - ω - νί - δος

Θ Γ Μ Γ Β Γ Λ Κ Γ Ο Μ  
 δά-[πε]-δον ἄ - θραυ - στον· ἄ - γί - οίς δὲ βω - μοι - οἶ - σιν

Γ Κ Μ Λ Κ Λ Μ Λ Μ Ο  
 Ἄ - φαι - στος αἰ - εἶ - θε<ι> νέ - ων μῆ - ρα τα - ού - ρων·

Κ Λ Γ Μ Ψ Θ Ι Θ Γ Θ Υ  
 ό - μου - οὐ δέ νιν Ἄ - ραψ ἄτ - μός ἐς [Ο]-λυμ - πον

Ο Μ Λ Μ Ο Υ Ο Μ Λ Μ  
 ἄ - να - κίδ - ν[α] - ται· λι - γύ δὲ λω - το - ός βρέ-μων

Λ Κ Λ Μ Λ Μ Υ Ο Μ Λ Μ  
 ἄ - ει - όλ - οι - οίς μέ - λε - σιν ὠι - δα - ἄν κρέ - κει·

Γ Λ Κ Γ Μ Κ Λ Μ Ο Υ  
 χρυ - σέ - α δ' ἄ - δύ-θρους κί - θα - ρίς ὕμ - νοι - σιν

Ο Μ Λ Μ Ο  
 ἄ - να - μέλ - πε - ται.

Figure 11: New transcription of the second section of Athenaeus' *Paeon* (Lynch 2022b)

## 4. Back to the future: 3D modelling and the Louvre aulos

Building upon this complex theoretical background, I have recently started to examine archaeological finds too—an independent source of evidence about ancient musical practice that is strikingly convergent with the technical, theoretical and cultural models outlined above.

The first part of this process consisted in producing 3D models of different ancient pipes, including the famous Louvre aulos (E10962). Figure 12 shows the model I produced in 2021 on the basis of photos as well as detailed measurements published in Hagel 2014a. An interactive version of this 3D model, augmented by music performed by Callum Armstrong on an accurate replica of these pipes, is now available on eMousikē.com (<https://www.emousike.com/louvreaulos>).

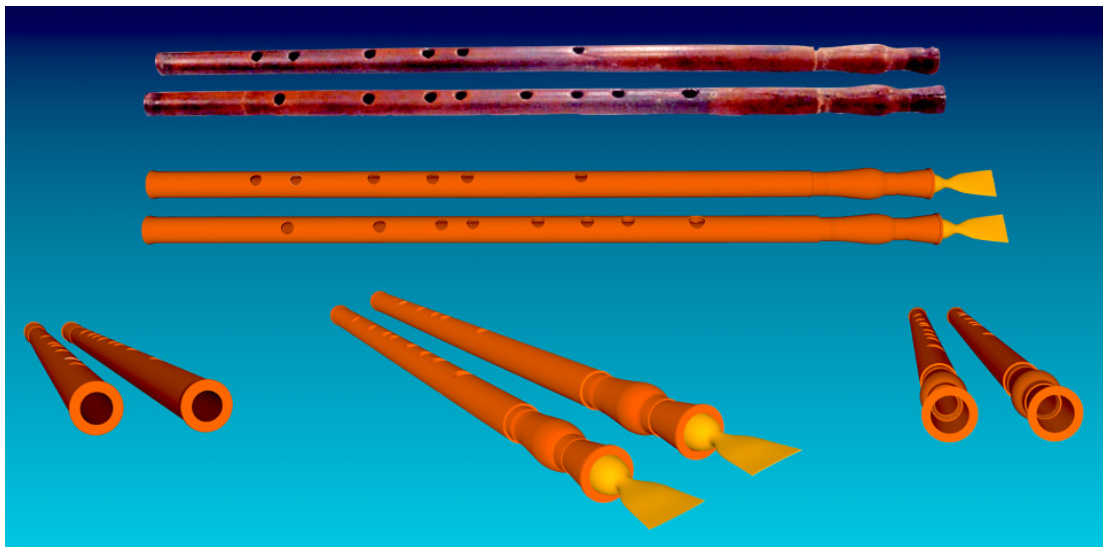


Figure 12: At the top, the Louvre aulos, inv. nr. E10962 (photo from Hagel 2014b, Figure 1); centre and bottom: new 3D model (Lynch 2021a), seen from different angles.

These wooden pipes of unknown dating are preserved in their entirety with the exception of the double-reeds that were originally inserted into the upper end of each pipe.<sup>33</sup> For these reasons, the Louvre aulos is an ideal candidate for acoustic and harmonic analyses.

The design of this instrument reflects a harmonic model that was firmly established in the 4<sup>th</sup> century BC. In keeping with this, Classical poets including Euripides refer to wooden double-pipes as Lybian *lōtos* (Eur. Tr. 544, *Hel.* 170, IA 1036)—a label that emphasises the particular type of African wood that was

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33 A broken specimen of a double reed from Ptolemaic Egypt is however preserved at the Musical Instruments Museum in Brussel (Inv. 3396).

employed to produce these instruments, as opposed to ivory or bone. But even though the design of the Louvre aulos is compatible with Classical sources, these particular pipes were most likely produced in Graeco-Roman Egypt; that is to say, the same context in which Ptolemy wrote his *Harmonics*.

Creating this model posed a number of technical challenges that were mainly related to the fact that these pipes feature a combination of different curved surfaces as well as variable diameters of their inner and outer bores, and of course a number of round holes set at different angles on their round surfaces. I had to test several softwares in order to find one that could handle this complexity but did not entail too steep a learning curve. I also found some visual interfaces hard to navigate efficiently, so I eventually switched to a different setup—namely an iPad with an Apple Pencil and an app called Shapr3D, which offers a fairly intuitive approach to CAD design.

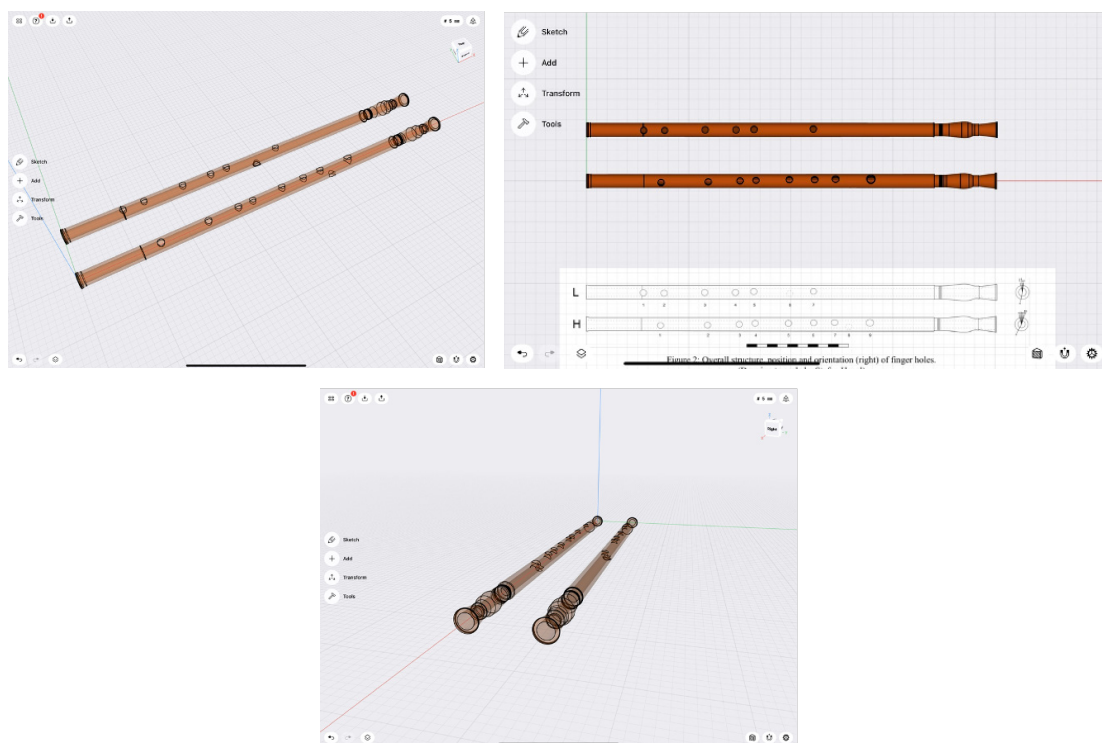


Figure 13: Modelling the Louvre aulos in Shapr3D.

As shown in Figure 11, the two pipes have been modelled in accordance with the measurements provided in Hagel 2014a, but a vital part of this instrument is still missing, namely its reeds (*aulētikoī kalamoi* or *donakes*).

No ancient reeds survive intact to this day, so how can we try to reconstruct them? A variety of material and literary sources fortunately provide us with solid evidence that allows us to identify and reproduce their essential features. First, a broken specimen of double reeds from Ptolemaic Egypt (MIM inv. 3396, Brussels) offers direct evidence of the practical use and general design of



ancient double-reeds. This material evidence is confirmed by an accurate sketch of a double-reed that was still attached to the lower pipe of the Berlin aulos (inv. 12461) at the time of acquisition (1894).<sup>34</sup>

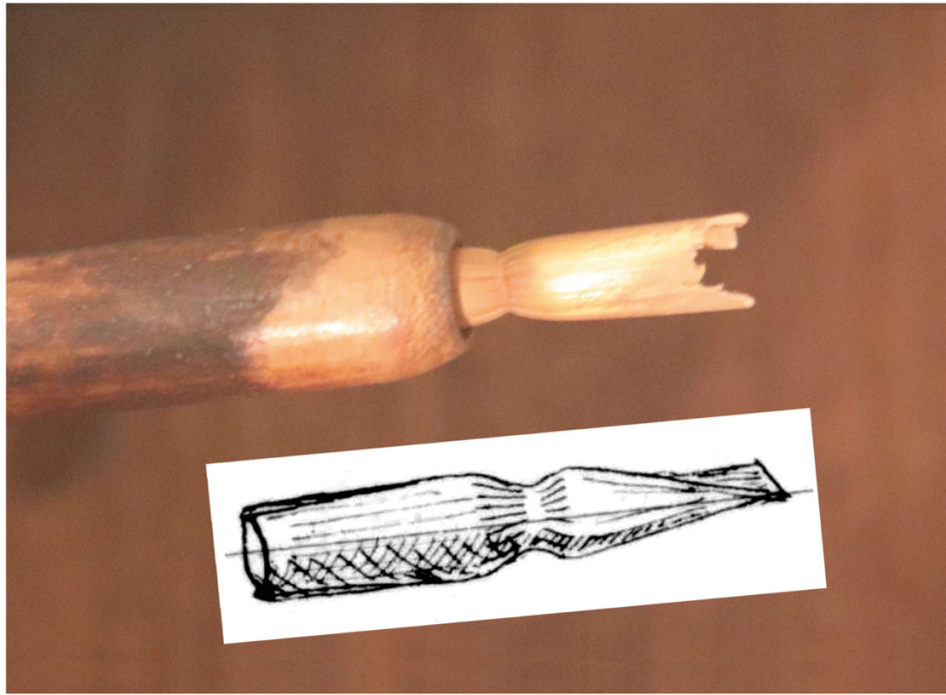


Figure 14: surviving double-reed, MIM inv. 3396, Brussels (Photo: © Katia Novoa, 2018), alongside a sketch of a double-reed preserved in the inventory book of the Egyptian Museum, Berlin (Hagel 2010, Fig.13).

Visual art also provides us with important evidence on the design of ancient reeds. Numerous visual representations of *auloi* in fact include double-reeds and fully conform to the design of the material specimens mentioned above, but also offer relevant information on possible variations in length that were appropriate for different types of pipes. Aristoxenus, for instance, mentions five different classes of *auloi*, ranging from small, high-pitched pipes for ‘girls’ and ‘boys’ to instruments suitable for adult men, including ‘kitharodic’ pipes as well as ‘complete’ and ‘hyper complete’ ones (fr. 101 Wehrli). As Aristoxenus points out elsewhere, these instruments were considerably different in register as well as size.<sup>35</sup> Different instruments obviously needed reeds of different lengths, and these variations are reflected in visual representations too (Figure 15).

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34 Cf. Hagel 2010. Hagel’s hypothesis about the ‘transposing’ nature of the scales produced by the Louvre aulos is, however, questionable; a different interpretation is offered below.

35 Aristox. *El. harm.* 26.8–11 Da Rios (‘the interval produced by the highest note of the “girl” aulos and the lowest note of the “hyper-complete” aulos is greater than three octaves’), discussed in Lynch 2020a, 142–3.



Figure 15 (top left): detail of a kylix attributed to the Gales Painter, Yale [1913.163](#) (Public domain); top right: detail of a kylix by Douris, Berlin, Antikensammlung F 3255 (Wikicommons); bottom left: detail of a kylix attributed to the Antiphon Painter, MET [96.9.36](#) (Public domain); centre: detail of a funerary marble relief, 2nd century AD, Musei capitolini, Rome S 1207 (Wikicommons); bottom right: detail of a red-figure amphora attributed to the Peleus Painter, British Museum 1847,0909.7 (Wikicommons).

So even though not all of these visual representations are directly relevant for the Louvre aulos, one point is clearly established by this converging evidence—namely the fact that *auloi* were played with double reeds, such as the ones used on modern oboes, and not single reeds, which are for instance used on modern clarinets.

The fact that auloi were reed instruments also means that they were closed pipes, and not ‘flutes’—a translation that is still very common, but is fundamentally misleading. The Greeks obviously had flutes too (*plagiauloi*), but these instruments had a completely different design and iconography.



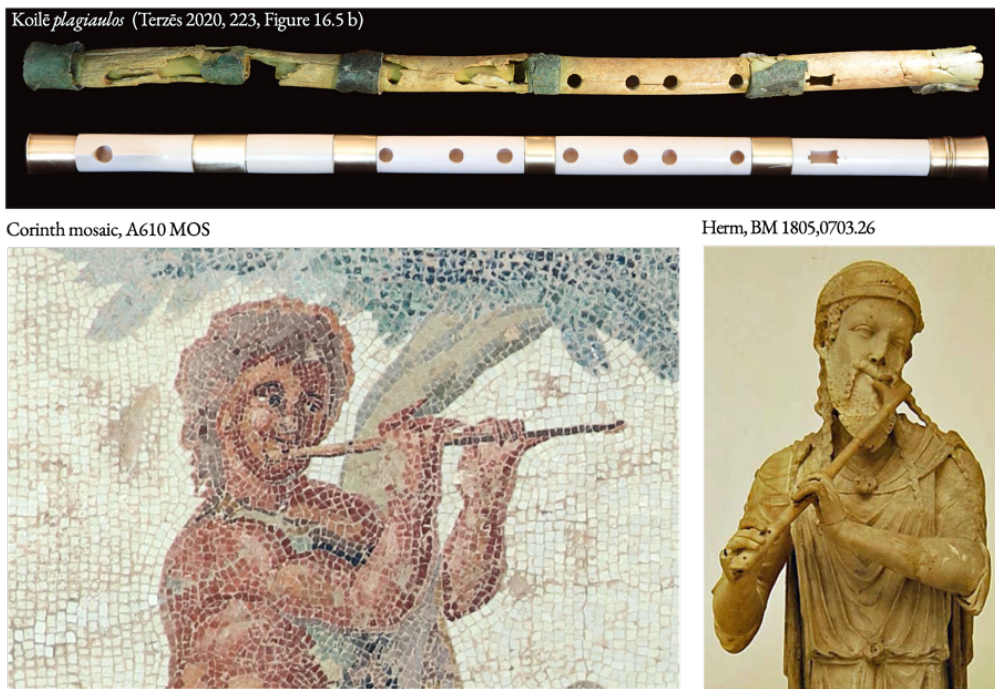


Figure 16 (top): the Koilē flute (*plagiaulos*), Terzēs 2020, 223; bottom left: mosaic with pastoral scene, 2<sup>nd</sup> cent. A.D., Archaeological Museum of Corinth A610 MOS (Wikicommons); bottom right: detail of a marble herm, British Museum [1805,0703.26](#) (CC BY-NC-SA 4.0).

Figure 16 shows that Greek flutes were played individually and functioned as open pipes. In contrast, *auloi* were played in pairs (Figure 15) and behaved like closed pipes. This structural difference has a number of important implications that we must take into account in order to try to reconstruct the scales that can be produced by a particular instrument. To this end, I have recently developed a simple tool that calculates the basic pitch of the notes produced by the finger holes of a given aulos on the basis of variable reed lengths. The calculator then automatically identifies the frequencies of these pitches with modern notes, accompanied by microtonal variations expressed in cents if necessary. This identification can be adjusted to different chamber pitches, allowing us to evaluate not only the structure of the scale itself but also its relationship to other instruments and tunings within the Greek harmonic system.

Much more sophisticated tools of this kind have been developed in recent years, including Hagel 2004 and 2014b and several others.<sup>36</sup> Even though these

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36 See esp. Andreopoulou & Roginska 2012, and Bakogiannis, Polychronopoulos, Marini, *et al.* 2020. Hagel 2004 offers a summary of the general principles he followed in creating a software that he subsequently employed in order to reconstruct the scales produced by a number of ancient auloi. As noted by Psaroudakēs 2008 and Andreopoulou & Roginska 2012, Hagel has never presented the details of the algorithm that powers his software; hence it is not possible for other scholars to evaluate the full set of theoretical assumptions that are embedded in Hagel’s algorithms.

tools are based on different methods and assumptions, the frequencies they identify are remarkably close to each other,<sup>37</sup> with differences that are often well within the 22-cent margin that Ptolemy identified as irrelevant in practical contexts.<sup>38</sup> This is a very encouraging result, and suggests that the frequencies identified by these tools are not too far from the notes that these instruments were designed to produce.

But this broad agreement on the basic frequencies produced by a given instrument does not automatically provide us with an interpretation of the harmonic and modal significance of these scales. In other words, the pitches identified by these kinds of tools are only a starting point, which must be interpreted in the light of cultural and technical evidence in order to produce historically informed reconstructions of the relative ancient scales.

In this connection, it is important to remember that double reeds are notoriously temperamental even in carefully controlled, and relatively standardized professional contexts. As modern oboe players can readily confirm, the very same pair of reeds can behave very differently in different conditions.

Ancient sources show that this was the case in the Greek world too and aulos players employed a variety of techniques to manipulate the pitch of individual notes, including variations in embouchure as well as covering different portions of individual finger-holes to modify the tuning of particular intervals.<sup>39</sup> Hence the scale patterns reflected by the position of finger-holes represented only a basic starting point that aulos players adapted in order to produce particular tunings (*harmoniai*), marked by distinctive harmonic ‘colourings’ (*chrōmata*) and ‘shades’ (*chroai*).

The pitches identified by modern calculators, and the relative reed lengths, must therefore be complemented by ancient theoretical evidence as well as practical experiments that try to reproduce the distinctive modal features of ancient scales on modern replicas of these instruments. The fruitfulness of this methodological interplay is illustrated by extremely successful projects that aimed at reproducing ancient aulos reeds.<sup>40</sup> These experiments involved

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37 See e.g. Table 3, in Bakogiannis, Polychronopoulos, Marini, et al. 2020, correcting two small misprints relative to the frequencies that correspond to Holes 8 and 9 (433.3 Hz and 490 Hz respectively in Hagel 2014b).

38 Cf. Ptol. *Harm.* 39.20, where practical differences up to 22 cents are described as ‘not worth distinguishing’ and practically insignificant (Ptol. *Harm.* 39.20: μηδενὶ ἀξιολόγῳ διαφέρειν; 40.2–3: ἐν οὐδετέρῳ τῶν ἐκκειμένων γενῶν συνίσταται τις ἀξιόλογος προσκοπή κτλ.).

39 See e.g. Ps.-Arist. *Probl.* 11.1 (quoted and discussed in Lynch 2022b, 423 note 15), Pl. *Phlb.* 56a, Aristox. *El. Harm.* 52.4–54.10 Da Rios, Arist. Quint. *De Mus.* 28.1–7: Proclus, *In Plat. Alc. I*, 197.13–15: ‘Each fingerhole (*trypēma*) of the aulos produces three notes at the very least, as they say, and more if the side-holes (*paratrypēmata*) are opened as well’.

40 See especially the experimental work undertaken by the ‘Workshop of Dionysus’ (<https://www.doublepipes.info>) and the European Music Archaeology Project more generally (<http://www.emaproject.eu>).

interdisciplinary teams of scholars and musicians who managed to produce working replicas of ancient reeds by combining material, visual and theoretical evidence with precious information about reed production and manufacture that is preserved in an extended passage of Theophrastus' *Historia Plantarum* (IV.2–11). Among other things, this passage indicates the best seasons for harvesting particular types of canes and their relative suitability for different types of *auloi* as well as different playing styles—evidence that has proved to be invaluable in the context of experimental archaeology.

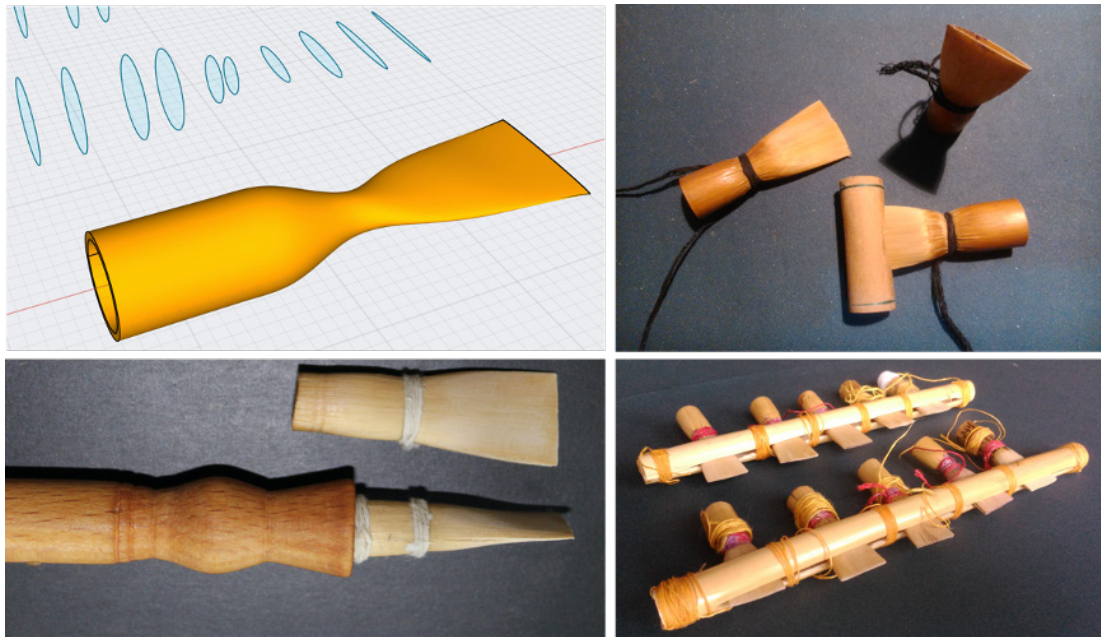


Figure 17 (top left): 3D model of aulos reeds (Lynch 2021a); top right and bottom: working replicas of ancient reeds produced by Callum Armstrong (photos ©Callum Armstrong).

Practical experiments on working replicas of ancient instruments are obviously necessary to confirm theoretical hypotheses, but can also yield useful insights in their own right. From a methodological point of view, it is however important to keep in mind that these practical insights do not automatically provide us with sound evidence about the possibilities and limitations of ancient instruments. Among other things, contemporary performances of ancient Greek music are not informed by a living musical tradition, and contemporary musicians do not have access to musical training provided by professional performers. This lack of advanced professional training, including often vital information that is passed down orally in music schools, makes it hard for us to assess the full capabilities of ancient instruments, especially but not exclusively in the case of advanced chromatic instruments such as the Pompeii pipes, as well as many-stringed *kitharai* and harps. For these reasons, practical experiments concerning Graeco-Roman music, and any interpretative insights arising from

them, must be confirmed by ancient evidence in order to qualify as sound historical evidence. Ethnomusicological comparisons with other musical traditions can likewise offer useful insights and correctives. These comparisons are especially effective in broadening our cultural horizons and help us overcome Western preconceptions about what is ‘natural’ or ‘desirable’ in musical terms, as well as other cultural biases that we unconsciously project onto ancient musical sources.

## 5. Next stop: a preview of books in progress

Bringing all of these strands together, I have recently produced a reconstruction of the scales and tunings produced by the Louvre aulos in two different settings that are respectively consistent with the defining features of the Classical and Imperial harmonic systems.<sup>41</sup>

This evidence will be discussed in detail in two books I am currently working on completing.<sup>42</sup> The second book effectively interrupted the completion of the first, but the documentary evidence discussed in the first part of the new book will in many ways set the scene for Plato’s interpretation of the ethical impact and cultural significance of different types of music and modes.

Even though the current drafts of both books are well above 80,000 words, completing them will take quite a bit of time as they cover the Classical as well as the Imperial harmonic systems and the relative musical documents, offering a substantial amount of new evidence. Among other things, the second book will show how the Imperial harmonic system, and the relative musical scores, are centred on the Hypolydian notation key, which effectively replaced the foundational role that the Dorian notation key had in the Classical system. In other words, the central reference point of the Imperial harmonic system was a semitone lower than its Classical counterpart, from Classical Dorian *mesē*  $F_3$  to Imperial Hypolydian *mesē*  $E_3$ —a structural change that had a substantial impact on the modal organisation of Imperial music. The new foundational role played by the Hypolydian key in the Imperial harmonic system is illustrated in a diagram featured in the earliest codex that preserves ancient Greek musical theory, Heidelbergensis Palatinus gr. 281 (Figure 18).

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41 On the Classical system, see Lynch 2022a and 2022b; on the Imperial system, Lynch 2023a.

42 Lynch forthcoming 1 and Lynch forthcoming 2.





which are fully consistent with the evidence provided by the Imperial musical documents as well as contemporary theoretical sources.

For the sake of methodological rigour, my analysis of the Louvre aulos scale is based on the frequencies published in Hagel 2014b. Thanks to the chamber pitch calculator included in Lynch 2021b, the musical value of these frequencies is however established on the basis of the standard pitch set by the Koilē flute (~432 Hz, Terzēs 2020).<sup>43</sup> Figure 19 illustrates the basic scales produced by the Louvre aulos as well as the relative Greek keys by means of modern notes and the corresponding Greek ones.

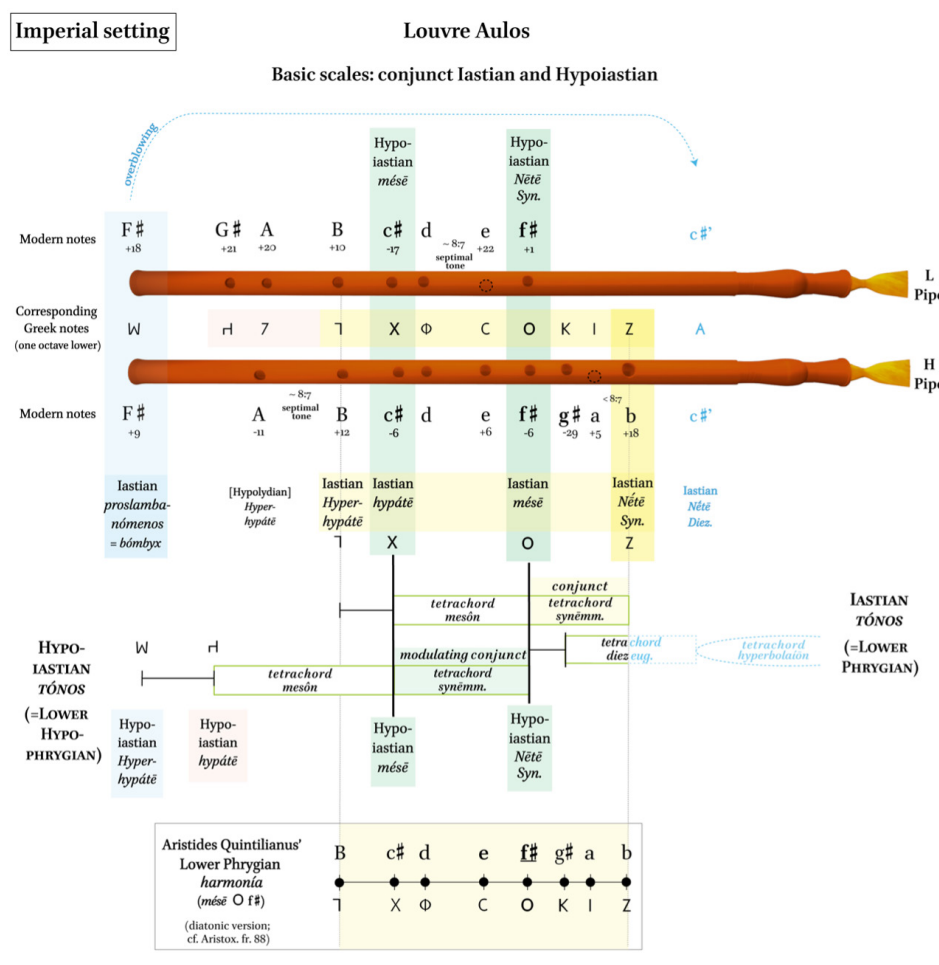


Figure 19: Louvre aulos: basic scales and keys, Imperial setting (Lynch 2022e).

43 As mentioned above, the Koilē *plagiáulos* was played without reeds, just like modern flutes, and is exceptionally well preserved. Taken jointly, these factors limit potential uncertainties about the scale produced by this instrument as well as practical deviations in pitch. For these reasons, we can take the frequency of its A4 ~432 Hz as a reliable reference point. On the reliability of flutes as indicators of historical pitch standards, cf. Haynes 2002, 7–9. This basic pitch could of course be subject to local variations, akin to those that occurred in the history of Western music: cf. Ellis 1880 and Haynes 2002.

The basic scales produced by the Louvre aulos conform to the lastian and Hypoiastian notation keys, which were called Lower Phrygian and Lower Hypophrygian in the Aristoxenian system.<sup>44</sup> In keeping with this, these scales correspond to the Classical Phrygian and lastian/Hypophrygian modes preserved by Aristides Quintilianus<sup>45</sup> as well as their Imperial equivalents recorded by Ptolemy.

These keys and tunings play a significant role in the Imperial musical documents too. The lastian/Lower Phrygian key is for instance employed in the famous Seikilos song (DAGM 23), a piece that conforms precisely to the Lower Phrygian tuning represented in Figure 19.

C Z̄ Z̄̇ KIZ̄ Ī̇  
 οσονζησφαινου  
  
 K̄ I Z̄̇ IK̄ O  
 μηδενολωσεν  
  
 C̄ Ōφ C K Z  
 λυπουπροσολι-  
  
 Ī̇ K̄i K C̄ Ōφ̇  
 γονεστιτοζην  
  
 C K O Ī̇ Z̄̇  
 τοτελοσχρο-  
  
 K̄ C C̄ CX̄Γ̇  
 νοσπαιτει

Ό-σον ζῆς φαί - νου,  
 μη - δὲν ὀ - λως σὺ λυ - ποῦ,  
 πρὸς ὀ - λί-γον ἔσ - τι τὸ ζῆν,  
 τὸ τέ-λος ὁ χρόνος ἀπ-αι - τεῖ.

Figure 20: The Seikilos song (Lynch 2020c, 287).

The book will also show how Ptolemy’s detailed account of the tunings employed by Imperial kitharodes allows us to take our analysis a step further. As shown in Figure 21, the basic scales produced by the Louvre aulos conform to the Phrygian and Hypophrygian tunings recorded by Ptolemy (*Hypertropa* and *Lastia*) not only with regard to their general octave species but also in connection with the fine tuning of key intervals. For instance, the septimal tone d–e (8:7) that is featured in Ptolemy’s Phrygian tuning (*Hypertropa*) corresponds to the interval

44 Cf. Lynch 2022a, Appendix 1

45 On the Classical setting and Aristides, see Lynch 2022f. Preliminary investigations suggest that the same methodology will allow us to reconstruct how other auloi, including early instruments such as the Pydna auloi as well as the complex Megara pipes, fit with the evidence of the Classical harmonic system and its late Classical developments discussed in Lynch 2022a–b.

produced by the relative holes of the L pipe of the Louvre aulos (Φ and C). Likewise, the septimal tone A–B that was distinctive of the ‘relaxed’ Iastian mode (*Iastia*) is produced by the lowest holes of the H pipe.

In the book, we shall also see how the unique microtonal shades embedded into the basic Phrygian scales of the Louvre aulos enabled aulos players to produce other tunings very easily. As shown in Figure 21, these modulations could be produced by half-covering one or two holes at most—a technique that has been mastered by Callum Armstrong. In other words, the Phrygian Louvre aulos could easily make room for the Imperial versions of the *harmoniai* played by the legendary Pronomus of Thebes: Dorian, Phrygian, and Tense Lydian, which came to correspond to the Imperial tunings called *Lydia*, *Iastia* and *Iastiaiolia*.

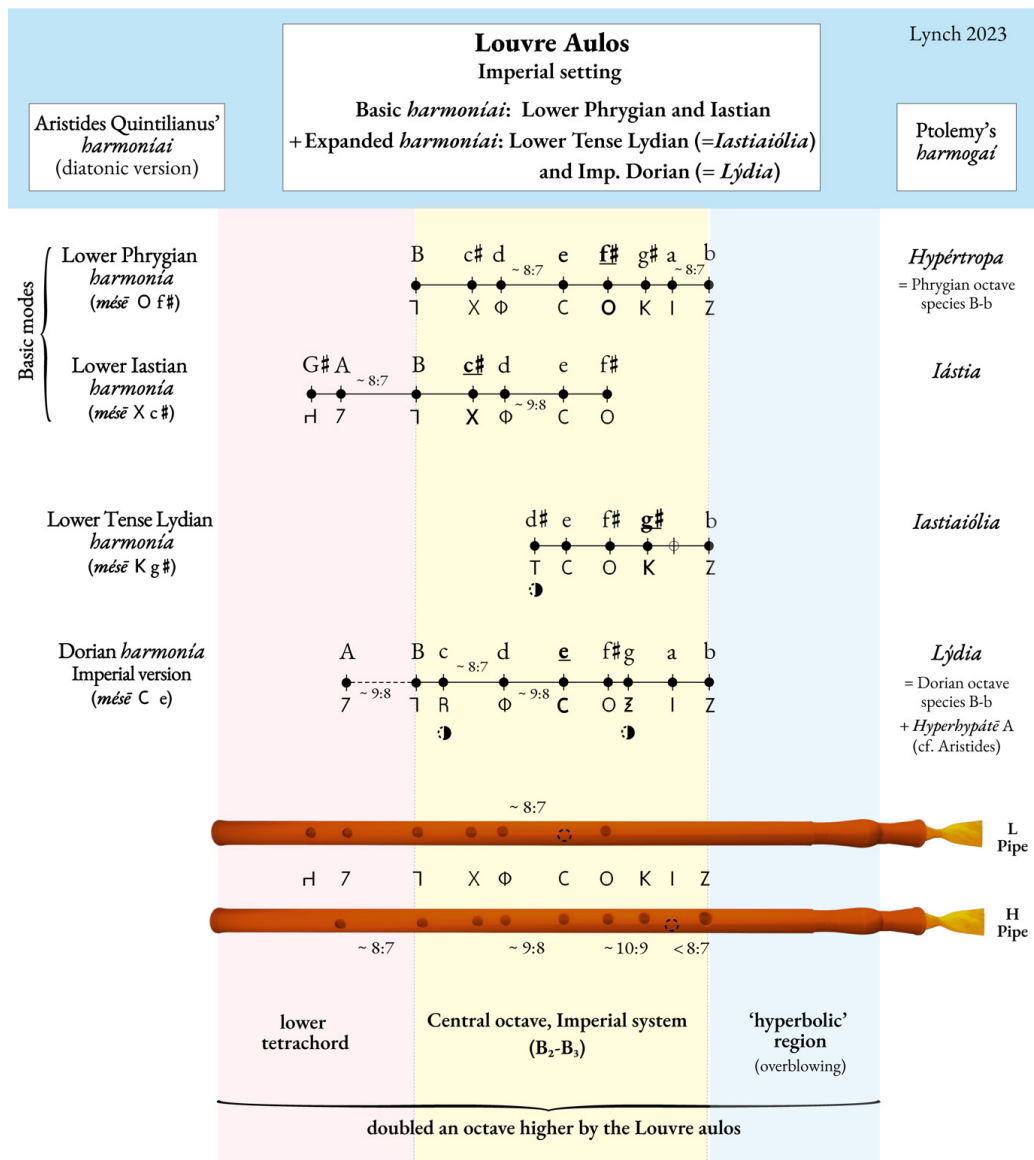


Figure 21: Louvre aulos—basic and expanded tunings, Imperial setting (Lynch 2023b).



## Bibliography

Andreopoulou, A., and Roginska, A. (2012). Computer-Aided Estimation of the Athenian Agora Aulos Scales Based on Physical Modelling. *Audio Engineering Society Convention Papers* 8695, pp. 1–10.

Bakogiannis, K., Polychronopoulos, S., Marini, D., Terzēs, C. and Kouroupetroglou, G. T. (2020). ENTROTUNER: a Computational Method Adopting the Musician's Interaction with the Instrument to Estimate its Tuning. *IEEE Access* 8: pp. 53185-53195, doi: 10.1109/ACCESS.2020.2981007.

Barker, A. (1984). *Greek Musical Writings 1*. Cambridge University Press.

Barker, A. (1989). *Greek Musical Writings 2*. Cambridge University Press.

DAGM = Pöhlmann, E. and West, M.L. (2001). *Documents of Ancient Greek Music: The Extant Melodies and Fragments*. Oxford University Press.

dDAGM = Lynch, T.A.C. (2021). Database 'Documents of Ancient Greek Music'. Zenodo: <https://doi.org/10.5281/zenodo.5181743>

Ellis, A.J. (1880). 'The History of Musical Pitch', *Journal of the Society for Arts* 28 (5 March), 293-336.

Hagel, S. (2004). Calculating *Auloi*—The Louvre Aulos Scale. In Hickmann, E. and Eichmann, R. (eds), *Music-Archaeological Sources: Excavated Finds, Oral Transmission, Written Evidence, Studien zur Musikarchäologie* 4.15, Rahden: Leidorf, pp. 373-90.

Hagel, S. (2010). Understanding the Aulos Berlin Egyptian Museum 12461/12462. In Eichmann, R., Hickmann, E. and Koch, L.-C. (eds) *Musical Perceptions—Past and Present: On Ethnographic Analogy in Music Archaeology*, Rahden, Westf.: Verlag Marie Leidorf GmbH, 67–87.

Hagel, S. (2014a). Data for Reconstructing the Louvre aulos. EMAP. Vienna. <http://www.doublepipes.info/wp-content/uploads/2014/04/Louvre-Aulos.pdf>

Hagel, S. (2014b). Better Understanding the Louvre Aulos. In Eichmann, R., Jianjun, F., Koch, L.-Ch. (eds), *Papers from the 8th Symposium of the International Study Group on Music Archaeology*. Rahden, Westf.: Marie Leidorf, pp.131–142.

Haynes, B. (2002). *A History of Performing Pitch: The Story of 'A'*. Scarecrow Press.

Levitan, W. (2023). Review of A Companion to Ancient Greek and Roman Music. Blackwell Companions to the Ancient World, edited by Lynch, T.A.C., and Rocconi, E. *Greek and Roman Musical Studies* (Online first). doi: <https://doi.org/10.1163/22129758-bja10057>

Lynch, T. (2016). Why are only the Dorian and Phrygian *harmoniai* accepted in Plato's *Kallipolis*? *Lyre vs. Aulos*. In Bravi, L., Lomiento, L., Meriani, A. and Pace, G. (eds), *Tra lyra e aulos. Tradizioni musicali e generi poetici*, Pisa-Bari: Fabrizio Serra Editore, 267–84.

Lynch, T. (2017). The Symphony of Temperance in *Republic 4*: Musical Imagery and Practical Models', *Greek and Roman Musical Studies* 5.1, 18–34.

Lynch, T. (2018). 'Without Timotheus, much of our *melopoiia* would not exist; but without Phrynis, there wouldn't have been Timotheus': Pherecrates' twelve strings, the strobilos and the harmonic *paranomia* of the New Music. *Greek and Roman Musical Studies* 6.2, 290–327.

Lynch, T. A.C. (2020a). Tuning the Lyre, Tuning the Soul: *Harmonía* and the *kósmos* of the Soul in Plato's *Republic* and *Timaeus*. *Greek and Roman Musical Studies* 8.1, 111–55.

Lynch, T. A.C. (2020b). Appendix—Diagrams of the ancient modes (*harmoniai*) as aulos and lyre tunings. In Lynch, T. A.C. and Rocconi, E. (eds), *A Companion to Ancient Greek and Roman Music*, Wiley-Blackwell, 489–95.

Lynch, T. A.C. (2020c). Rhythmics. In: Lynch, T. A.C. and Rocconi, E. (eds), *A Companion to Ancient Greek and Roman Music*, Malden: Blackwell, pp. 275–295.

Lynch, T. A.C. (2021a). The Louvre aulos—interactive 3D Model. <https://www.emousike.com/louvreaulos>

Lynch, T. A.C. (2021b). Louvre Aulos scale calculator 1.0. Zenodo. <https://doi.org/10.5281/zenodo.5515303>

Lynch, T. A.C. (2022a). Unlocking the Riddles of Classical Greek Melodies I: Dorian Keys to the Harmonic Revolution of the New Music and the Hellenistic Musical Documents. *Greek and Roman Musical Studies* 10.2, 383–415

Lynch, T. A.C. (2022b). Unlocking the Riddles of Classical Greek Melodies II: the Revolution of the New Music in the Ashmolean Papyrus (DAGM 5–6) and Athenaeus' *Paeon* (DAGM 20). *Greek and Roman Musical Studies* 10.2, 416–467.

Lynch, T. A.C. (2022c). 'Rhythms "in armour" and rhythms "by the finger": Socratic humour and rhythmic sophistry in Aristophanes' *Clouds* (636–53)'. In Gostoli, A., Zimmermann, B. (eds), *Nuove volute di versi. Poesia e musica nella commedia greca di V e IV sec. a.C.*, Göttingen: Vandenhoeck & Ruprecht, 245–66.

Lynch, T. A.C. (2022d). 'The Canon' diagram (Heidelbergensis Palatinus gr. 281, fol. 173 v) and the structure of the Hypolydian Unchanging Perfect System. Zenodo. <https://doi.org/10.5281/zenodo.6627046>

Lynch, T. A.C. (2022e). Louvre aulos: basic scales and keys, Imperial setting. Zenodo. <https://doi.org/10.5281/zenodo.7213558>

Lynch, T. A.C. (2022f). Louvre aulos: basic scales and keys, Classical setting. Zenodo. <https://doi.org/10.5281/zenodo.7213545>

Lynch, T.A.C. (2023a). Unlocking the Riddles of Imperial Greek Melodies: the 'Lydian' Metamorphosis of the Classical Harmonic System. Under evaluation. Preprint on Zenodo. <https://doi.org/10.5281/zenodo.6927929>

Lynch, T.A.C. (2023b). Louvre aulos: basic and expanded *harmoniai*, Imperial setting. Zenodo. <https://doi.org/10.5281/zenodo.7635422>

Lynch, T.A.C. (forthcoming 1). *Plato's Musical ēthos and Classical Greek modes, instruments and rhythms* [2023 draft]. Zenodo. <https://doi.org/10.5281/zenodo.7636576>

Lynch, T.A.C. (forthcoming 2). *Ancient Greek melodies and the Invention of the Harmonic System: from Euripides to Early Christianity*. [2023 draft]. Zenodo. <https://doi.org/10.5281/zenodo.7524698>

Lynch, T.A.C. and Rocconi, E. (eds) (2020). *A Companion to Ancient Greek and Roman Music*, Wiley-Blackwell.

Nehamas, A. (1985). *Nietzsche, Life as Literature*. Harvard University Press.

Psaroudakēs, S. (2008). The Auloi of Pydna. *Studien Zur Musik-Archäologie* 6.22: 197–216.

Terzēs, C. (2020). Musical Instruments of Greek and Roman Antiquity. In Lynch, T. A.C. and Rocconi, E. (eds), *A Companion to Ancient Greek and Roman Music*, Malden: Blackwell, pp. 213-227.

Wallace, R. W. (2015). *Reconstructing Damon: Music, Wisdom Teaching, and Politics in Perikles' Athens*. Oxford University Press.

West, M.L. (1992). *Ancient Greek Music*. Oxford University Press.