Department of Languages<br>Faculty of Arts<br>University of Helsinki

# Greek Meter: An Approach Using Metrical Grids and Maxent 

Erik Henriksson

## DOCTORAL DISSERTATION

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Supervisors Mika Kajava, PhD, Professor<br>Department of Languages<br>University of Helsinki<br>Marja Vierros, PhD, Associate Professor<br>Department of Languages<br>University of Helsinki<br>Kalle Korhonen, PhD, Docent<br>Department of Languages<br>University of Helsinki<br>Reviewers Bruce Hayes, PhD, Distinguished Professor<br>Department of Linguistics<br>UCLA<br>Kevin Ryan, PhD, Professor<br>Department of Linguistics<br>Harvard University<br>Opponent Bruce Hayes, PhD, Distinguished Professor<br>Department of Linguistics<br>UCLA

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#### Abstract

Standard presentations of ancient Greek poetic meter typically focus almost exclusively on identifying and classifying the repeatable syllable-weight-based patterns found in Greek poetry. This dissertation, by contrast, seeks to understand why selected Greek poets arranged their words in just those patterns, instead of some others. Counter to the prevailing approach in classics, which defines meters as strings of short and long positions, meters are here viewed as abstract rhythmic patterns, made concrete by the phonological representations of verses. A main goal is to explicitly characterize the well-formedness conditions on the correspondences between these abstract patterns and actual lines. The study is couched in the framework of generative metrics.

The dissertation is divided into seven chapters. Chapter 1 sets the scope and context of the study and provides a brief rationale for the proposed approach by pitting it against mainstream descriptive Greek metrics. The Greek metrical tradition is approached in relation to other quantitative traditions, with the aim of showing that recent insights from comparative metrics, as well as music psychology, may shed new light on the metrical practices of Greek poets. Chapters 2 and 3 comprise the theoretical framework and methodology. Chapter 2 lays out the basic assumptions about metrical structure that underlie this study. It is also discussed that though generative metrics is right to distinguish between concrete verses and abstract rhythmic patterns, the long-standing hypothesis that meter is a stylization of phonology remains controversial. Chapter 3 offers a detailed review of the main statistical method used in the study, called Maximum entropy density estimation (Maxent), which is here applied to construct explicit analyses of poets' assumed metrical knowledge. The chapter also introduces a novel method of incorporating language models into Maxent grammars using priors, designed to factor out effects of lexical statistics from metrical analysis.

Chapters 4 to 6 form the main empirical part of the dissertation. Chapter 4 analyzes four Greek meters (trochaic tetrameter catalectic, Archaic and tragic iambic trimeter, comic iambic trimeter, and anapestic dimeter) using Maxent. I demonstrate that the quantitative patterns in these selected meters can be plausibly analyzed in terms of hierarchical metrical grids and a small number of natural rhythmic constraints. Grammars incorporating language-model-based priors suggest, furthermore, that some of the ostensibly anti-rhythmic properties of the meters under scrutiny can be explained by the statistical patterning of Greek words. Chapter 5 focuses on the more complex


quantitative patterns of Sappho and Alcaeus' verse. I address the lack of rhythmic regularity that characterizes these patterns from the perspective of Paul Kiparsky's recent proposal, according to which some forms of early Greek verse employ syncopation. I show that, with some revisions, Kiparsky's theory can account for Sappho and Alcaeus' metrical forms and treat them as underlyingly periodic. Chapter 6 returns to defend the distinction between meter and verse rhythm, arguing against a theory that strives to unify the two by representing meter using phonological constraints alone. As I argue, the approach suffers from theoretical and empirical weaknesses, both in general and as applied to the analysis of Greek meter.

Chapter 7 summarizes the main results of the dissertation, discusses them from a broader perspective with an emphasis on the modern history of metrical scholarship, and outlines directions for future research.

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## Chapter 1

## Introduction

### 1.1 What is meter in (Greek) poetry?

When the rhythm of a linguistic passage is regularized to the extent that it becomes the governing principle of composition, METER is said to occur (Winslow 2012, p. 872). Poetic meters are conventionalized rhythmic patterns that both use and pull against the rhythms of ordinary language, using LANGUAGE PROSODY (a.k.a. suprasegmental phonology) as their material basis. Specifically, meters depend on syllabic prominence contrasts, as defined by phonological theory, and phonological phrasing (Kiparsky 1975, 1977; Hayes 1989b). Thus, languages with stress accent are very likely to have stressbased meters (e.g., English, German), tonal languages tend to develop meters that constrain tonal patterns (e.g., Middle Chinese; Chen 1979), and weight-sensitive languages typically have meters based on syllable weight (e.g., Tashlhiyt Berber; Dell and Elmedlaoui 2008).

Ancient Greek meter is quantitative, that is, it regulates the distribution of heavy ( H ) and light ( L ) syllables in lines. Like most weight-sensitive languages, Greek employs the so-called Latin criterion (Ryan 2019, p. 3) to mark the binary H vs. L distinction: any syllable that ends in a short vowel is light, and all the rest are heavy. Lines of Greek verse are syllabified without regard to word boundaries, so that a line such as khrēmátōn áelpton oudén estin oud' apó́moton ${ }^{1}$ is syllabified khrē-má-tō-ná-elp-to-nou-dé-nes-ti-nou-d'a-pó̃-mo-ton. This yields

[^0]a regular trochaic tetrameter line. In standard handbooks of Greek meter (e.g., Maas 1962; Korzeniewski 1968; West 1982a), the L and H syllables are called "short" and "long", respectively, underlining the fact that greater phonological weight tends to correlate with greater duration (Ryan 2019, p. 9; Ryan forthcoming). However, the actual timing of ancient Greek verse in performance is a subject of debate (e.g., Pearson 1990; West 1992; Mathiesen 1999; Pöhlmann and West 2001; Hagel 2008; Silva-Barris 2011; Lynch 2020), and so, arguably, the concept of syllable weight is more appropriate for describing the syllabic patterns of Greek verse (see also Allen 1973, p. 53-55).

A prevalent tendency in metrical traditions across languages, including Greek, is that even the strictest of verse forms can be written using many different syllabic patterns; (1), for instance, is just one of the 14 quantitative shapes that Archilochus uses in his trochaic tetrameters. But instead of selecting patterns at random or equally likely, poets tend to use some patterns systematically more often than others, largely by intuition (e.g., Jakobson 1985, p. 70). Explaining what leads them to do so is one of the main goals of the discipline of metrics. The primary sources of evidence are the verses themselves ("internal evidence"; Tarlinskaja 2014, p. 10), recorded performance practices (e.g., Dell and Elmedlaoui 2008; Schuh 2011; Proto and Dell 2013), as well as native speaker judgements about what makes for a well-formed line in a given meter (e.g., Attridge 1996; Hayes and Kaun 1996).

In the case of ancient Greek poetry, what survives is more than 100000 lines of poetry, ${ }^{2}$ a few post-Classical scraps of musical notation (Pöhlmann and West 2001), and zero native speakers. In short, a formidable collection of silent texts has come down to us; and though we do know something about the prosody of classical Greek (Devine and Stephens 1994) and ancient theories of meter and rhythm (e.g., Mathiesen 1985; Pearson 1990; Lynch 2020), many scholars find it difficult, if not impossible, to explain why Greek poets chose to use just the patterns they did. Modern research has tended to avoid the explanatory questions altogether (see Lidov 2014 for a review), focusing instead on developing descriptive systems of the observable patterns (e.g., Maas 1962; Raven 1962; Snell 1962; Korzeniewski 1968; Dale 1968; West 1982a; Sicking 1993).

[^1]Due to the painstaking work of these scholars, we now have a good picture about the different ways in which Greek poets used, combined, and varied patterns such as (1) above - but explanations are still, for the most part, lacking.

The common suspicion that we can never truly understand Greek meter (Barker 1991, p. 71) goes back to Nietzsche (1870-1871, published 1993). Specifically, Nietzsche argued that in Greek poetry "the rhythmical interest lay precisely in the timequantities and their relations, and not [...] in the dum-di-di of the ictus (beat)" (1884, tr. Middleton 1967, p. 59, original emphasis). These time-quantities, as Nietzsche understood, were inherent in the durational contrasts between the L and H syllables in the Greek language; and since there was no evidence for a dynamic stress accent in Greek, ${ }^{3}$ Nietzsche reasoned that any analysis of Greek verse rhythm must operate in strictly durational terms. ${ }^{4}$ Further, Nietzsche believed that since the durational ratio of H and L was unlikely to be exactly $2: 1$ in ordinary speech, the rhythms of Greek verse, too, must have been fundamentally irrational and antagonistic to precise measures (Porter 2000, pp. 152-156). This assumed temporal indeterminacy of Greek versification, combined with the lack of ictus, made Greek versification in Nietzsche's vision utterly incommensurable with modern rhythms. As Porter (ibid., p. 136) says, Nietzsche's theory about Greek verse rhythm has turned out to be one of his most lasting contributions to classical scholarship. For example, Paul Maas, who had read Nietzsche (1962, p. 4) and whose work is fundamental for nearly all of later Greek metrics, famously claimed that "scarcely any facet of the culture of the ancient world is so alien to us as its quantitative metric" (ibid., p. 3). ${ }^{5}$

The picture looks less grim, however, in light of recent work in comparative metrics and the psychology of rhythm. First, comparative metrics has revealed fundamental

[^2]similarities between quantitative and stress-based meters, reducing some of the alleged exoticism of Greek verse. Quantitative meter may have vanished from Europe (Maas 1962, p. 3), ${ }^{6}$ but it thrives in many African languages (e.g., Hausa, Somali, Tashlhiyt Berber) as well as in Asia (e.g., Japanese, Telugu, Thai) (Gordon 2007, p. 208-209). Recent work in the indigenous quantitative meters of Afroasiatic languages, in particular, has demonstrated that quantitative systems tend to conform to the same basic principles of eurhythmy as accentual meters (Schuh 1999, 2001, 2010, 2011, 2014; Dell and Elmedlaoui 2008; Hayes and Schuh 2019). Second, it is now understood that those basic principles are of a more abstract nature than the prosodic material they relate to. Specifically, many researchers think that meter in poetry is best characterized as a mental abstraction of rhythm that governs poetic composition but is not coextensive with actual verses (e.g., Tomaševskij 1923; Kolmogorov 1968; Bailey 1975; Jackendoff 1989; Hayes and Kaun 1996; Hayes and MacEachern 1998; Lerdahl 2001; Hayes and Moore-Cantwell 2011; Schuh 2011; Tarlinskaja 2014; Hayes and Schuh 2019; Kiparsky 2020, and many others).

In this view, poetic meters are much like musical meters, whose defining property is the perceptual alternation of METRICAL ACCENTS, that is, perceptually weaker and stronger beats inferred from dynamic, temporal, or tonal cues (Vos 1977; Fraisse 1982; Lerdahl and Jackendoff 1983; Clarke 1999; London 2002; Huron 2006; London 2012; Honing 2014, etc.). Research in rhythm perception suggests that meter induction is innate (e.g., Honing 2012; Honing et al. 2015; Kotz et al. 2018), though enculturation affects which particular shapes are perceived (van der Weij et al. 2017). Thus, analyzing the quantitative patterns of Greek verse in terms of metrical accentuation is not, at least in principle, "historically false", as Nietzsche claimed (1870, tr. Halporn 1967, p. 235). Nor does it seem plausible that Greek poets would normally have left the perception of metrical accents as a matter of "arbitrary choice" for their audiences, as West (1982a, p. 23) conjectures. If, as London (2012) says, metrical structures serve as a "ground against which the continuing temporal patterns may be discerned" (p.13), it arguably makes more sense to assume a priori that the durational patterns of Greek

[^3]verse had some such definite metrical "ground" that they were designed to evoke. ${ }^{7}$ This seems likely seeing in particular how inseparable poetry was from music and dance in the essentially oral Greek culture (e.g., Olsen 2017).

### 1.1.1 Goals of the dissertation

This dissertation is an effort to make sense of some of the metrical forms that Greek poets used, based on the assumption that some more abstract rhythmic structure underlies the quantitative patterns found on the surface. The proposed analyses, which make use of statistical (Chapter 4) and more traditional qualitative (Chapter 5) methods, are couched in the framework of generative metrics (see Blumenfeld 2016 for an overview), a core idea of which has always been to distinguish between abstract meters and their surface manifestations as actual verses (e.g., Halle and Keyser 1966, 1971a; Kiparsky 1975, 1977). Generative metrics holds that metrical analysis should not stop at descriptive generalizations or the cataloguing of observable metrical forms, but strive for explicit and empirically valid accounts of the metrical intuitions of poets. Recent work, in particular, tends to follow cognitive psychology in characterizing meter as a mental abstraction of rhythm (e.g., Hayes et al. 2012; Blumenfeld 2015; Kiparsky 2018; Hayes and Schuh 2019), but the representation of this construct remains a subject of debate. A common assumption in generative metrics is that poetic meters are stylizations of phonological form and based strictly on the same linguistic categories that are relevant in ordinary speech (e.g., Jakobson 1960; Kiparsky 1973; Hayes 1989b; Prince 1989; Golston and Riad 2000; Blumenfeld 2015; Riad 2017; Kiparsky 2020). Chapter 2 and Chapter 6 defend an alternative view, according to which poetic meters are hierarchical rhythmic structures similar, though not necessarily identical, to musical meters.

Besides striving for explicit accounts of individual metrical idioms, generative metrics has typological goals. A theory of Universal Metrics (e.g., Hayes 1988, 1989b) would characterize a typological space of possible meters using a small number of general principles, and situate existing metrical systems in it (Blumenfeld 2016, p. 423; for proposals, see Hanson and Kiparsky 1996, Blumenfeld 2015). A typological approach

[^4]with a smaller scope would be to explain why, within a single metrical system, only some meters are observed among all conceivable ones (see Golston and Riad 2000 for a typology of Greek meters). This dissertation has an even more modest goal: it seeks plausible rhythmic explanations for the frequency distributions of different quantitative patterns in a selection of meters, based on the premise that in each case, there is an abstract rhythmic pattern underlying the actual lines. Although a number of general rhythmic principles will be formulated for Greek verse (§3.4), a typological study using these principles is beyond the scope of this dissertation.

The statistical framework I adopt in this study, called Maximum entropy density estimation, or MAXENT ${ }^{8}$ for short (Mohri et al. 2018, Ch. 12), is reviewed in Chapter 3 and applied to an analysis of Greek verse forms in Chapter 4. Maxent, whose origins are in 19th century statistical mechanics (Boltzmann 1868; Gibbs 1902), Information Theory (Jaynes 1957), and machine learning (Berger et al. 1996; Della Pietra et al. 1997), has recently become popular in diverse fields of research, including natural language processing (Berger et al. 1996), species habitat modeling (e.g., Phillips et al. 2006) and theoretical phonology (e.g., Goldwater and Johnson 2003; Hayes and Wilson 2008). It has also been used in a number of metrical studies (cf. Hayes and Moore-Cantwell 2011; Hayes et al. 2012; Hayes and Schuh 2019), though, to my knowledge, not previously with ancient Greek. Besides applying the method to new material, the present work introduces a novel way of using Maxent to factor out unintentional effects of language-intrinsic rhythmic patterns from metrical analysis (§3.3.4).

### 1.2 Traditional Greek metrics: an overview

This section looks at some of the basic assumptions and concepts of "traditional" Greek metrics, by which I mean the standard descriptive-durational outlook represented by English, German, and Italian textbooks such as Maas (1962), Halporn et al. (1963), Korzeniewski (1968), West (1982a, 1987), Gentili and Lomiento (2003), and others. The section has two purposes: 1) to introduce metrical terms that will be useful later on, and 2) to vindicate an alternative approach by pointing out a number of shortcomings of traditional metrics.

[^5]A basic ingredient of traditional theory is the distinction between syllables and abstract Metrical Positions (MP). ${ }^{9}$ There are three kinds of MPs, two of which are specified for length,$-($ or PRINCEPS $)$ for long and $\smile($ BREVE $)$ for short, and a third one whose length is unspecified, $\times($ anceps $) .{ }^{10}$ The mapping of syllables to MPs is straightforward: princeps positions may contain H and sometimes LL (this is called RESOLUTION and notated $-\simeq$ ), breves are $L$ (and rarely LL), and ancipitia can be either $L, H$, or sometimes LL. In addition, there are BICEPS positions ( $\tau$ ), which are in fact two consecutive breves occupied alternatively by H or LL (the latter is called CONTRACTION).

Responsion is an essential concept in traditional metrics. There are two kinds: 1) INTERNAL RESPONSION refers to the repetition of sub-patterns (METRA, FEET) within lines, and 2) EXTERNAL RESPONSION denotes the quantitative parallelism between verses. For example, an anceps realized as L or H in one line may externally respond to either L or H in another. In stichic meters, lines respond to each other in sequential manner, but responsion also applies to groups of lines in STROPHIC compositions (a modern parallel is the verse or chorus structure of song lyrics). Responsion is crucial for any kind of metrical analysis, because it indicates what kind of patterns poets consider to be rhythmically compatible. Particularly illuminating are lines in which inverse configurations of $\smile$ and - stand in responsion. For instance, in Sappho (fr. 95-96 Voigt) the following patterns respond:
 $-\cup \cup-\smile-\cup-$ $-\cup-\cup-\cup \smile-$

The responsion of mixed rhythms like (2) was noted already by ancient metrists, who discussed the phenomenon in terms of metrical FEET: an IAMB ( $\checkmark-)$ may respond with a TROCHEE $(-\cup)$, and vice versa (for the ancient references, see Silva-Barris 2011, pp. 40-44). On a foot-based analysis, the responsion in (2) looks slightly less chaotic:

[^6](3)
\[

$$
\begin{aligned}
& \cup-,-\cup, \cup-, \cup- \\
& -\cup, \cup-, \cup-, \cup- \\
& -\cup,-\cup,-\cup, \cup-
\end{aligned}
$$
\]

In other types of verse, responsion is attested between $-\cup \smile$ (DACTYL), $\smile \smile-$ (ANAPEST) and -- (SPONDEE) as well as between $-\cup, \smile-$ and $\backsim$ (TRIBRACH). The reason that just these patterns respond is the same which makes contraction (LL $>\mathrm{H}$ ) and resolution $(\mathrm{H}>\mathrm{LL})$ possible in some meters: L and H syllables have a durational ratio close to 1:2 (e.g., West 1987, p. 6). But as the existence of the $\times$ position indicates, responsion can also be quantitatively free.

Metron denotes a sub-pattern repeated within a line in some meters, such as in IAMBIC TRIMETER $(x-\smile-$ repeated three times). It is important to point out that metra describe purely quantitative periodicities and are not in Greek generally matched by phrase boundaries, as opposed to many other metrical traditions (e.g., Hayes 1988). In asymmetric meters, where some kind of patterning may be identifiable in external but not internal responsion, the corresponding term is COLON.

As can be seen, the symbols $-, \cup, \times, \simeq$ and $\varpi$ are simply a notational shorthand for the syllabic sequences that can be found in verses. In other words, they are designed to describe quantitative variation in verses rather than explain the metrical practices of poets. As a move towards explanation, West (1982a, pp. 18-19) formulates the following rules of Greek metrical composition:
(4) No consecutive princeps positions $(*--)^{11}$

No more than two MPs between two princeps positions ( $*->2$ MPs - )
Each princeps must have an adjacent short syllable (e.g., ${ }^{*} \times-\times$ )
No adjacent short syllables and anceps positions ( ${ }^{*} \cup \times,{ }^{*} \times \cup$ or ${ }^{*} \times \times$ )

Patterns such as $\ldots-\succ-\times-\cup \ldots, \ldots-\cup \cup-\ldots$ and $\ldots \smile-\times-\cup \smile \ldots$ respect these rules and are indeed common in the Greek metrical repertoire. But as West acknowledges, the rules are not absolute and are sometimes violated. Here are some examples:

[^7]

In addition to the above examples, ${ }^{*-}-$, is violated by Pentameter $(-\bar{\sigma}-\sigma$ $--\cup-u-$ ), which was used as the second line of the elegiac couplet, one of the most popular forms of Greek verse throughout antiquity. So the fact that every poem written in that meter violates ${ }^{*}--$ at least once makes the rule look less than general. ${ }^{12}$

Additional rules concern the beginnings and endings of lines. A line cannot begin $\smile-\times$ and must end either $\smile-$ or $\smile--$, but many exceptions are again found (for example, the second line of (5) ends in --- , and so do many lines written in anapestic meters). West (1982a) calls his rhythmic rules "general principles" (p. 19) but does not discuss why they would have obtained such a status in the Greek system.

### 1.2.1 Beyond descriptive durationalism

The traditional approach, as we have seen, describes meter almost exclusively in terms of long and short elements. The phonological basis of this binary distinction was established in antiquity; detailed accounts survive in treatises by Dionysius of Halicarnassus (1st c. BCE), Hephaestion (2nd c. CE), and Aristides Quintilianus (3-4 c. CE). Even earlier, Aristotle (4th c. BCE) speaks about the measuring of language by long and short syllables (Categories 4b32-37). Importantly, the distinction did not only apply to metrical measures but was understood as a phonological fact of the Greek language (Aristotle, Rhetoric 1408b; Dionysius of Halicarnassus, On Literary Composition 17). In addition to being sensitive to syllable weight, ancient Greek had a distinctive tone or pitch accent (e.g., Probert 2006), which, however, appears to have been completely ignored in versification. ${ }^{13}$ The current consensus is that archaic and classical Greek did not have a phonological stress, though some researchers have argued for its existence on metrical or linguistic grounds (e.g., Allen 1973, 1987; Golston 1990; Nagy 2010).

[^8]In sum, the descriptive style of durationalist metrics is supported by the phonological facts of Greek.

But the traditional approach seeks no rigorous answer to the arguably most fundamental problem: why did the poets choose to arrange the L and H syllables in the ways they did, instead of some other ways? To quote Halle and Keyser (1966, p. 190), one of the earliest critics of traditional (English) metrics: "Since the allowed deviations [from a canonical base form] share only the property of being included in a list, why could not other deviations also be included in such a list?" (cited in Blumenfeld 2016). West's (1982a) rhythmic principles rule out some of the unattested patterns, but, again, no explanation is given as to why it was sometimes bad to write consecutive longs (*--) or longs separated by too many non-longs ( ${ }^{*}->2$ MPs - ) or any of the other avoided combinations; nor are the deviations explained.

I will now point out some further issues in the traditional approach. First, the MP-based notation is not always appropriate even for purely descriptive purposes. For example, iambic trimeter is schematized by West (1982a, p. 40) as follows:


The stacked first two positions ( $(\underset{\times \sim}{\times-\bar{u}})$ are meant to be read as alternatives (i.e., a line can start either $\cup \sim-$ or $\times \simeq \simeq$ ). Notating the beginning more concisely with $\simeq \simeq \simeq \simeq$ would not be accurate, because if the line starts with $\cup$, the second MP must always be instead of $\underline{u}^{\sim}$; in short, the line cannot start with $\sim w{ }^{\text {. }}$. The avoidance of long stretches of $L$ syllables is a general property of Greek verse (and some forms of prose; see, e.g., Devine and Stephens 1994, pp. 107-108), but the MP-based notation cannot easily capture this generalization. To this it can be added that MPs can only indicate the "allowable" patterns in a given meter but not how poets actually make use of these allowances. For example, (6) suggests that iambic trimeters can start with $-\cup$ just as well as $\backsim \backsim-$, but misses the important fact that the former appears much more rarely.

More seriously, the traditional notation can lead to wrong generalizations. For instance, when the first $\times$ of an iambic trimeter line is substituted with $\cup \sim$, the line is said to start with an anapestic foot ( $\smile-$; e.g., West 1982a, p. 88; West 1987, p. 26), a rhythmic figure primarily associated with anapestic meters. This suggests that $\smile \cup-$ in iambic trimeter is rhythmically identical to that same figure in an anapestic context. But this can hardly be true. In iambic trimeter, the initial $\smile-$ responds most often
with spondees $(--)$ or iambs $(\checkmark-)$, and only very rarely with dactyls $(-\backsim \checkmark)$. In anapestic meters, however, anapestic feet respond with spondees and dactyls, while iambs are strictly forbidden. Evidently, the sequence $\smile \checkmark-$ is rhythmically different in these two meters. Similarly, in trochaic meters spondees respond with trochees ( $\smile)$, while in dactylic hexameter they are used interchangeably with dactyls, which, in turn, are very rare in trochaic meters. Furthermore, poets writing hexameters often end words in between the two short syllables of the dactyl $(-\cup \mid \nu)$, but when an iambic trimeter verse starts with the same sequence, word-breaks in that position are almost banned (Devine and Stephens 1994, p. 108). Similar arguments have been against traditional analyses of other metrical traditions, including Finnish (Kiparsky 2006b), English (Bjorklund 1979) as well as German and Russian (Gasparov 1996); see also Blumenfeld (2016).

The descriptive approach is also ill-suited for comparative work, as Prince (1989, p. 50) points out. Although metrists use the same technical terminology (foot, metron, etc.) to analyze prosodically different metrical systems, the sort of analysis that focuses on concrete surface patterns ignores the abstract similarities between, for example, quantitative iambs ( $\smile-)$ and stress-iambs (unstressed-stressed). As was said above (§1.1), much of traditional Greek metrics explicitly denies that quantitative and accentual units are commensurable; but recent comparative work suggests otherwise. To discover the fundamental similarities between metrical systems, we must look beyond the surface.

### 1.2.2 On the concepts of rhythm and meter

Confusingly, metrists and cognitive psychologists use the terms "rhythm" and "meter" in different ways. In the field of metrics, meter has been traditionally understood as a property of texts and is often defined as a syllabic pattern (or some abstraction thereof) with a specified length and a given name (e.g., the Greek iOnic Dimeter is the eight-syllable $\smile \smile-ー \smile \smile--)$. Rhythm, on the other hand, has been associated with performance and the experiencing of poetic meter, and defined in terms of strong and weak beats, grouping, variation, and so on (Attridge 2016). This usage of the terms has ancient roots, perhaps as early as the 4 th century BCE (Mathiesen 1985).

Cognitive psychologists, on the other hand, mean by rhythm the perceptual categorization of continuous time-intervals between events in terms of low integer ratios
(e.g., 1:1, 1:2), which, when repeated with some regularity, are perceived as rhythmic patterns (e.g., Fraisse 1982; Honing 2013; Kotz et al. 2018). Unlike metrists, most cognitive psychologists use rhythm to refer primarily to the temporal organization of events and only secondarily to accentuation (Schulkind 1999; London 2002; cf. Hasty 1997). When psychologists talk about "strong" and "weak" beats, they do not mean the intensity peaks of the signal itself (a.k.a. phenomenal accents), but listeners' expectations of them, constructed upon attending to the "temporally unfolding musical surface" (London 2002, p. 531). What defines meter, on this view, is such sensing of accentuation imposed on a rhythmic pattern, a process which has been understood to be a kind of neural entrainment (i.e., synchronization) (London 2012; Levitin et al. 2018). Chapter 2 explores poetic meter from this cognitive perspective.

### 1.3 Common properties of quantitative meter

This section looks at some of the basic features of the quantitative Greek metrical system from a comparative perspective. As will be discussed, Greek shares many of its metrical properties with other quantitative systems. Some of these properties, such as the avoidance of LLL and the splitting of LL in resolution (§1.3.5), have been used as evidence for various theories of Greek prosody (Devine and Stephens 1984, 1994; Steriade 2018), but the fact that they are also attested elsewhere suggests that they may have a more general rhythmic basis, as I discuss below.

### 1.3.1 Syllable weight

Like most other weight-based metrical systems (Gordon 2007), ancient Greek meter employs the binary criterion that syllables ending in a short vowel are light (L) and all the rest are heavy $(\mathrm{H})$. Thus, Greek verse patterns can be adequately described using only the symbols $L$ and $H$; the DACTYLIC HEXAMETER, for instance, is a pattern consisting of six metra that must be either HLL or HH, except the last one which is always HH (see $\S 1.3 .2$ below). But it should be emphasized this is far from being a complete description of the quantitative picture. As Ryan (2011a) has shown, Greek poets are also gradiently sensitive to different types of H syllables. It is possible that these intricacies are connected to performance practices, where the "longer" heavies would perhaps have been associated with longer musical notes, and vice versa.

The weight dichotomy of quantitative metrics is based on the sound structuring of language itself. As linguists have known for a long time, many languages have phonological processes sensitive to syllable weight, and though languages differ as to how the weight is determined, here too the distinction is predominantly binary (Gordon 2007, 2017; Ryan 2019). Intriguingly, however, the criteria for weight need not be the same in metrics and purely phonological processes. For instance, in Gordon's (2007, pp. 207-2010) survey of 17 quantitative metrical systems, all exhibit the same criterion as Greek (i.e., light if and only if (C)V), but two of the examined languages (Malayalam and Telugu) have stress rules where (C)VC must be interpreted as L. Gordon also makes the interesting note that all known quantitative metrical systems except Berber have phonemic vowel length contrasts, whereas languages that lack this contrast (e.g., Russian or English) or have recently lost it (Persian) rarely have quantitative meters. It appears that quantitative metrical systems require a "sufficiently robust" (ibid., p. 2010) phonological distinction of syllable weight.

Even if languages appear to make the same weight distinction in metrics, there are differences in syllabification between languages, and even between meters in the same language. In the Greek of Homeric epic, for instance, clusters of stops followed by liquids or nasals are normally split between syllables (e.g., ték.na $=\mathrm{HL}$ ) whereas in the dialogue parts of Greek plays the norm is to compress them as onsets (té.kna $=$ LL). Both Vedic Sanskrit and Finnish are cluster splitters (Ryan 2019, p. 137; Suomi et al. 2008, p. 67), but Classical Sanskrit prefers to form onsets from intervocalic clusters (Vaux 1992). Moreover, the metrically relevant representation of linguistic passages may differ from ordinary phonology in various ways. The poetry-specific PARAPHONOLOGICAL (Kiparsky 1977, p. 190) patterns often draw from historical forms of the language (Kiparsky 2020). For instance, in French, the word violettes is normally pronounced with two syllables [vjolct], but in poetry it may take the archaic form [vijolcta], which has four (Dell 2011). A similar example in Homeric Greek is the syllabification of some words as if they still contained the sound /w/ (digamma) which had disappeared by Homer's time from ordinary speech. Thus, for instance, a wordfinal syllable preceding the word /(w)anaks/ "king" (LSJ, s.v.) is treated as H due to the historical digamma. An example of a synchronic paraphonological process known in Greek and Vedic Sanskrit is correption, or the shortening of long vowels before another vowel, especially at word-end (West 1982a; Gunkel and Ryan 2011).

As pointed out in $\S 1.1$ above, the quantitative patterns of Greek verse are determined without regard to breaks between words. This kind of resyllabification is common in quantitative meters generally (e.g., Latin, Persian, Sanskrit, Tamil) but by no means a universal (cf. Finnish, Hausa, Somali). Due to this rhythmic continuity (or SYNAPHEIA), word-final syllables with a short vowel are ambiguous: for instance the word a.ris.tê.es ("best" (plural), LSJ, s.v.) is scanned LHHH before a consonant-initial word, but would be LHHL before a vowel. This does not mean, however, that Greek verse is completely agnostic about word boundaries. On the contrary, most Greek meters have strict rules about word placement: in iambic trimeter, for instance, wordfinal H syllables are practically banned in the last anceps but obligatory either after the second anceps or two positions later (West 1982a, pp. 40-42). However, the fact that resyllabification applies line-internally indicates that there were no long pauses in recitation line-medially.

### 1.3.1.1 Mora-counting and weight-sensitivity

In this dissertation, I treat metrical weight as defined by the moras they contain (Hyman 1985; Hayes 1989a): a L syllable has one mora, and a H syllable two. Under the moraic theory, quantitative meters can be organized to a typological continuum where at the one end are meters that count the number of moras per line, and at the other meters that are sensitive to the organization of H and L syllables in verses. ${ }^{14}$ The best-known example of a mora-counting metrical tradition is Japanese poetry, which is based on lines that count to 5 or 7 (e.g., kata-uta 5-7-7, tanka 5-7-5-7-7, haiku 5-7-5). ${ }^{15}$ Although Japanese, just like ancient Greek, distinguishes between L and H syllables, its meters are insensitive to their organization beyond the number of moras they provide. At the other end of the continuum are meters that enforce a fixed quantitative pattern of H and L syllables; an example is the Persian motaqaareb meter (Hayes 1979). Most quantitative meters, however, fall somewhere between these two

[^9]extremes. For instance, the Hausa rajaz meter determines the number of moras per metron (maximally seven) but limits the range of allowed syllabic patterns (Hayes and Schuh 2019). Vedic Sanskrit meters, on the other hand, organize H and L syllables into recognizable patterns but do not observe the moraic equivalence of LL and H (Arnold 1905).

Ancient Greek employs both Hausa and Vedic-like systems. In some forms of early Greek lyric (discussed in Chapter 5), lines have a fixed syllable count and a semifixed pattern of H and L syllables, resembling the Vedic system (Meillet 1923). In other meters, the syllable counts of verses may vary due to resolution and contraction. Hexameter, as noted above, is one such meter: each non-final metron must start with H and end in either H or LL. In yet other meters, both the syllable and mora counts are variable; iambic metra, for instance, take different shapes including LHLH, HHLH, LHLLL, LLLLH—but not something like HLHLL, which has an allowed number of moras but an illicit quantitative profile. Finally, anapestic meters require only that metrical positions are mapped to either H or LL, so long as consecutive positions within metra are not LL.

### 1.3.2 Final indifference

In all known quantitative meters, line-final syllables are treated as indifferent to weight, and typically interpreted as H due to lengthening of the final syllable or a pause at the end (Ryan 2019, p. 139). This is called final indifference. Recall from above that the Greek hexameter has six dactylic/spondaic feet, except that the final foot cannot end in LL. This can be interpreted as a final indifference effect: if the last metron were $-\sigma$ (to use traditional notation), a final HLL would in fact be HLH, as there can be no L syllables line-finally; but HLH is not a valid foot in the hexameter.

As Ryan (2013, 2019) shows, however, poets are not truly indifferent to final positions. Instead, they tend to at least subtly prefer mapping final positions to their expected syllabic weight. Thus, in both Homeric hexameter and its Latinized version used by Virgil, line-final syllables tend to be genuinely $H$, respecting the four-mora default of the hexameter metron. Similarly, in a Latin meter that ends in the trochaic sequence HLHH where the line-final position is expected to be L, Ryan (2013) found that the poet Catullus prefers $L$ syllables in the final position (see also Ryan 2011a). Interestingly, however, patterns that would be expected to end in $L$ are generally rare-
in other words, trochaic meters tend to be catalectic (see $\S 1.3 .6$ below). For this reason, final indifference is also known as brevis in (elemento) longo ("short in long position"; Maas 1962, p. 34).

### 1.3.3 Final strictness and initial laxness

Another putative universal of quantitative metrical systems is the tendency for weight patterns (excluding the "free" final position) to increase in regularity towards the ends of metrical groups. This principle of final strictness, as it is called, is best known to affect lines (Fabb 2002, pp. 173-175) and in some cases also line-internal sub-patterns such as hemistichs and cola (Ryan 2016). Although final strictness has been known for over a century (see, e.g., Arnold 1905 for Vedic) there is no consensus about its origin. One possible linguistic explanation comes from natural prosody (e.g., Hayes 1983) where intonational groups have been observed to be right-headed even in otherwise leftheaded prosodic systems (e.g., Hayes and Lahiri 1991; Kahnemuyipour 2003). Fabb (2014) offers another explanation, claiming that lines are processed as units in working memory, whose cognitive load final strictness would alleviate. Another cognitive account (deCastro-Arrazola 2018, Chapter 4) suggests that constituent-final regularity follows from the synchronization of neural clusters to metrical periodicities, strengthening with each processed stimulus (see also Arrazola 2021). It seems probable, as deCastro-Arrazola (2018, p. 98) points out, that no single explanation can account for all the phenomena related to final strictness.

The opposite of final strictness is the freer choice of rhythmic patterns at the beginnings of metrical groups than at endings (INITIAL LAXNESS). Interestingly, whereas final strictness affects grouping structures gradiently, initial laxness is more closely associated with the absolute left edges of groups, most often line beginnings. This is exemplified by the meter of the Beowulf, which allows ANACRUSIS or an extra initial syllable (Bliss 1958); the so-called line-initial trochaic inversion of English iambic pentameters (Hayes 1983); Persian quantitative meters, which may occasionally start with an extra L (Hayes 1979); the Greek iambic metron with its initial anceps ( $\times$ -$\smile-)$ as well as many Greek lyric verse forms, where the first one or two syllables are quantitatively semi-free (see Chapter 5).

### 1.3.4 Anceps

Anceps is a position that can be either L or H (or rarely LL). Contrary to what many 20th-century metrists thought, there is now a consensus that anceps is not a position with an intermediate duration somewhere between L and H (e.g., Dale 1968; Maas 1962; West 1970), but simply an unregulated position in the meter (e.g., Devine and Stephens 1975). Quantitatively free metrical positions are attested in many traditions (e.g., Greek, Latin, Arabic, Hausa), and in each case, they usually appear line- or metron-initially, in accordance with initial laxness (see $\S 1.3 .3$ above). In Greek, anceps positions can normally only stand next to princeps positions (§1.2), that is, positions that are H or exceptionally LL.

### 1.3.5 Sequences of light syllables

Many Greek meters (and even some types of prose; C. D. Adams 1917) avoid stretches of more than two L syllables. Such sequences are not uncommon in the Greek language (e.g., e.gé.ne.to "came into being", LLLL), and so the fact that poets avoid them calls for an explanation. Although explanations have been offered as part of theorizing about ancient Greek phonological structure (Devine and Stephens 1994; Steriade 2018), it should be noted that LLL sequences are also avoided in other metrical traditions, for instance Hausa (Schuh 2014; Hayes and Schuh 2019) and Arabic (Greenberg 1949). As Schuh (2014, p. 12) argues, LLL-avoidance is perhaps best explained in rhythmic terms: long sequences of L could disrupt the perception of periodic beats in metrical verse.

In some Greek meters (notably iambic trimeter and trochaic tetrameter), a princeps position can sometimes be resolved ( $\mathrm{H}>\mathrm{LL}$ ). However, resolution is constrained in that it cannot occur if a word-break would occur in between the L syllables, and is avoided when a word-break would follow (Devine and Stephens 1984, p. 60). Similar rules are known in other languages: in the English iambic pentameter, for instance, normally monosyllabic positions can have two syllables, but not split, except with proclitics (Kiparsky 1977; Hanson 1992). The same rule holds in Latin ("Ritschl's law"; Radford 1903), Old English (Carroll 1993) and, to a lesser degree, in Old Norse poetry (Suzuki 2014). Thus, there may be a general rhythmic explanation for the cross-linguistic avoidance of resolution involving a word-break. One such explanation would be the marking of prosodic boundaries with final lengthening, which is known
from a number of languages (e.g., Beckman and Edwards 1987; Edwards et al. 1991; Turk and Shattuck-Hufnagel 2007); the added duration would strain the rhythm of the (already strained) resolved position.

### 1.3.6 Truncation

It is a characteristic of Greek verse that patterns have truncated variants, with a syllable missing at either end of the line (Parker 1976). For instance, lines that regularly end in the iambic sequence $\ldots \times-\smile-$ have variants that end trochaically $\ldots \times--$ and the Aeolic pattern glyconic $(g l) \times \times-\smile \smile-\smile-$ has a "headless" variant $\times ー \smile \smile-\smile-$. The more common form of truncation appears to have been at the end of the line (or CATALEXIS), with every major Greek verse form having a catalectic variant in addition to (or in place of) an acatalectic form (West 1982b). Catalexis normally appears at the end of a group of cola, couplets or larger periods (Parker 1976).

Some of the Greek truncated variants have been argued to originate in a IndoEuropean metrical tradition, mainly on the basis of parallels in Vedic poetry (Meillet 1923; West 1973a, 1982b), as will be discussed in more detail in Chapter 5. Truncation is not specific to the Indo-European tradition, however; ${ }^{16}$ on the contrary, it is a putative universal of metrical systems (Brailoiu 1952; Burling 1966). In living metrical traditions, catalexis generally indicates an empty beat (or sequence of beats) at the end of the line or a group of lines, allowing the poet to articulate a metrical structure by slowing down without disrupting the pulse (Hayes and MacEachern 1998). As Hayes and MacEachern (ibid.) and Kiparsky (2006a) argue, rhythmic cadences where final positions are empty naturally mark group endings; they call this the principle of SALIENCY. From a functional perspective, catalexis also may help the performer to draw a breath between verses (e.g., Pearson 1974). Catalexis in Greek most likely worked similarly; and there is also some evidence from musical documents of final lengthening having been associated with it (West 1992, p. 209).

Initial truncation (or "headlessness", a.k.a. ACEPHALY) is related to the difference between iambic and trochaic rhythms: trochaic lines can sometimes be interpreted as headless iambic lines, in particular when such lines are used in an otherwise iambic

[^10]context (see, e.g., Kiparsky 1977, for examples of trochaic lines among Shakespeare's iambic pentameters). Acephaly is not documented, to the best of my knowledge, to work the other way around, turning trochaic meters into iambics (however, some meters truncate entire feet at the beginning; see, e.g., Burling 1966; Schuh 2011. A rhythmic interpretation that suggests itself is that acephaly is the deletion of an anacrusis (i.e., upbeat) at the beginning of lines.

### 1.3.7 Syncopation

In quantitative meters, HL sequences can sometimes be replaced with LH, and vice versa. Descriptively speaking, it is a kind of quantitative metathesis, the reordering of durations (Golston and Riad 2005, p. 108). However, on the assumption that underlying the concrete surface patterns is a more abstract rhythmic pattern (i.e., a "meter", in the music-psychological sense), quantitative metathesis can be treated as syncopation, the reversal of an expected rhythm. In traditional Greek metrics, syncopation is called ANACLASIS, a marginal property of Greek verse (Wilamowitz-Moellendorff 1921, p. 235). Kiparsky (2018) develops a compelling argument that some of the most common meters used by the Greeks (including the hexameter, elegiac distich, and many other lyric meters) derive from a syncopated Indo-European proto-meter. As I discuss below (§5.2), syncopation is not limited to the Indo-European quantitative tradition, but is also attested in many meters in languages of the Chadic family (e.g., Schuh 2001). Some quantitative meters in addition employ hemiolas, i.e., optional replacements of a normally tetrasyllabic sequence by a moraically equivalent trisyllabic rhythm (e.g., LHLH > HHH). It is attested in, for instance, Ngizim songs (ibid.).

### 1.4 Summing up

The mainstream traditional approach to Greek meter, which focuses on the identification and classification of observable patterns in verses, strives for descriptive accuracy but cannot-in part by design - explain the metrical practices of Greek poets. Much work in this tradition, as discussed in this chapter, has been carried out in the shadow of Nietzsche's pessimistic view about the extent to which explanation in Greek metrics is possible; hence the long-standing focus on observation. The approach taken here is different: it starts from the assumption that lines manifest abstract rhythmic representations and tries to characterize the properties of verses that qualify them as
well-formed with regard to the underlying pattern. As was suggested here, the emerging picture of how meters work across languages and traditions makes it possible to start analyzing the Greek metrical system from such a different perspective.

## Chapter 2

## Meter as an abstract rhythmic pattern

A cornerstone of generative metrical analysis is the distinction between abstract meters and the actual rhythmic patterns of verse. This chapter delves into that distinction, focusing on the theoretical conception of meter as an abstract rhythmical scheme internalized by the poet. As I discuss, much previous work in generative metrics has assumed that meter in poetry is entirely grounded in language, and that consequently, the study of meter should involve strictly linguistic methods and assumptions. This chapter tries to demonstrate that poetic meters have many properties that can be more easily explained on the assumption that meter in poetry is a rhythmic abstraction much like musical meter.

### 2.1 Poetic meter: a structural and temporal phenomenon

Poetry, in particular the metered kind, is aural almost by definition: it is the regularized patterning of speech sounds that distinguishes it from other forms of verbal art. ${ }^{1}$ Rhythmically free verse was almost non-existent before the mid-19th century (Cooper 2012), and especially in traditional cultures, poetry has typically been associated with music and dancing (Banti and Giannattasio 2005; Dell and Elmedlaoui 2008; Schuh 2011). Furthermore, according to Brogan et al. (2012b), even the kind of poetry that is intended to be spoken (instead of sung or chanted) was until recently normally performed in an artificially rhythmic manner, with an emphasis on rhythmic regularity at

[^11]the cost of phonological naturalness. Metered verse has also been characterized as "language written in such a way as to make possible the experiencing of beats" (Attridge 1996, p. 9). In short, metrical verse is nothing if not musical language.

It is equally trivial, however, that the fabric of poetry is language, and that poetry can only be rhythmic owing to the same abstract linguistic categories (stress, syllable weight, phrasing, etc.) that convey the rhythms inherent to ordinary spoken language. Modern linguistic approaches to poetic meter tend to emphasize the grounding of meter in language, not just with a view of the poetic text as a linguistic object, but also as concerns its superadded regularities (Fabb 2017). The idea that metrical form depends on linguistic categories emerged in the Russian formalist school in the early 20th century (Červenka 1984), and was epitomized by its most famous proponent, Roman Jakobson, as follows (1933; tr. Jakobson 1979, p. 148): "linguistic values, not bare sounds, are the building blocks of verse, and the role that prosodic elements fulfil in a given linguistic system is decisive for verse. [...] Verse and recitation are two different problems: there are elements which do not require any acoustic implementation whatsoever, but nevertheless, have great significance for verse". The classic example that Jakobson brought to bear on the separation of verse and its temporal realization came from Serbian epics, where every line has an obligatory word-break after the 4th syllable that is nevertheless completely inaudible in normal recitation (ibid., p. 195). Later work has found more evidence for Jakobson's theory. For example, in some types of sung poetry, poets choose phonological patterns within narrow rhythmic constraints and yet perform the patterns in rhythms that obscure, to a lesser or greater extent, the motivation for said constraints (e.g., Fischer 1959; Dell and Elmedlaoui 2008; Schuh 2011; Hayes and Schuh 2019; Oras 2019). Poetic meter has also been shown to have access to a different phonological grammar from ordinary spoken language. In the Finnish Kalevala meter, for instance, superficial exceptions to basic metrical rules disappear when one looks at partly derived phonological forms instead of the phonological (or phonetic) surface (Kiparsky 1968; see Malone 1982 and Hayes 1988, p. 228, for similar examples from other languages). In sum, there is reason to believe that meter in poetry is in ontological terms a more abstract structural phenomenon (Brogan et al. 2012a, p. 878) than simply a reflection of how the lines are meant to be performed.

### 2.1.1 Narrow metrics

Based on the idea that meter is a property of a linguistic object with no necessary acoustic correlates, Jakobson and his followers hypothesized that meter is best described in exclusively linguistic terms (Jakobson 1960, p. 365), without any extra-systemic ingredients of analysis (cf. Chatman 1960). Jakobson famously claimed that the fundamental property of verse is the projection of Paradigmatically equivalent linguistic elements to SYntagmatic recurrences; and this refers not only to (groups of) syllables but to any kind of linguistic structure such as morphology and syntax (Kiparsky 1984). In other words, all phenomena in verse are on this view analyzable as manifestations of the principle of parallelism, that is, the sequencing and opposition of linguistic elements that are in some way alike - or by design opposed - be it sound, grammatical structure or meaning (Jakobson 1960, p. 368).

Another pivotal idea in Jakobson's poetic theory was, on the one hand, the distinction between VERSE DESIGN (i.e., poetic meter) and VERSE INSTANCES (actual verses), and on the other, the separation of Delivery design (musical meter) from delivery instances (musical rhythms). In this architecture, verse design is the abstract pattern that individual lines can manifest using linguistic "materials" such as phrasing, word stress and syllable weight; and the delivery design is another abstraction which governs the way poets recite or sing their verses. The delivery and verse components, Jakobson further emphasizes, should not be mistaken for the same thing - a performance is an event whereas a poem is an enduring linguistic object (p. 366). Later research, especially within generative metrics, has turned Jakobson's "distinction into an exclusion", creating a kind of narrow metrics (Kiparsky 2010; see Fabb and Halle 2008 for a particularly strong version of such a theory, criticized by, e.g., Kiparsky 2009; Hayes 2010; Vaux and Myler 2011). In fact, however, Jakobson only warned against the "erroneous identification" (1960, p. 367) of the delivery and verse components, and never seems to have insisted on their complete separation.

### 2.1.2 Broad metrics

An argument against narrow metrics is that there are many examples of poetic meters that can be meaningfully described only when performance practices are taken into account-in other words, meters can have properties that are not formal properties of the text (Kiparsky 2010). One such property are silent beats: a verse can be quite
irregular on the phonological surface, but when one listens to how it is performed, a regular alternating pattern emerges due to a short rest somewhere in the line. An example is the quantitative KAAMIL meter used in some West Chadic languages (Schuh 2011, pp. 218-222). The verses in this meter, which are always performed by singing, have the syllable pattern $\varpi-\smile-\varpi-\smile-$; but as Schuh points out, its deeper regularity only emerges in a performance context. When the poets sing the kaamil verses, there is a rest after the 4 th position in each line, which corresponds to a single phonological mora in the text. When the rest is taken into account, kaamil is essentially the same as another (unnamed) Chadic meter, $\bar{\tau}-\bar{\iota}-\bar{u}-\cup-$, which has the missing mora; and indeed, both are performed in the same musical measure. It appears, then, that any purely textual metrical analysis of kaamil is bound to be off the mark. ${ }^{2}$ Broad metrics, as Kiparsky (2010) calls the approach that incorporates performance conventions in poetic metrics, seems to be appropriate not just for sung verse, but for any type of poetry that is meant to be performed orally. Robert Frost, for instance, has been recorded to read his own poems with silent beats at line-endings (Paschen and Mosby 2001; see Kiparsky 2010 for more examples).

But if poetic rhythm turns out to be best described based on how it manifests temporally, one might question the very existence of poetic meter as a separate concept. The idea that performance is the only relevant component in the analysis of poetic rhythm (contra Jakobson) has been explored in some recent studies within the framework of generative metrics (e.g., Hayes and Kaun 1996; Hayes and MacEachern 1998; Schuh 2011; Proto and Dell 2013; Dell 2015); other recent work, however, seems to uphold Jakobson's original distinction. For example, Hayes and Schuh (2019) analyze a Hausa meter (see §2.2.4.2 below) solely in terms of textual properties and argue that it "exists as an abstraction underlying all of its various sung realizations" (p. e284). Similarly, Dell and Elmedlaoui (2008) show that Tashlhiyt Berber sung poetry is based on purely textual regularities that can all but vanish in performance; Banti and Giannattasio (1996) make the same case for Somali metrics. Following Kiparsky (2006a), it seems to make most sense to adopt a MODULAR view where the performance and linguistic meters are analyzed as separate systems (i.e., the Jakobsonian verse and

[^12]delivery components), which are distinct but "mutually accommodated and causally connected" (Kiparsky 2018, p. 78).

It is not well understood, however, how the musical and textual meters are connected. Hayes and Schuh (2019) consider some possibilities. First, it might be that poets first compose a text using a poetic meter (i.e., verse design) and then use that metrically "validated" text as raw input to the musical textsetting. This is surely correct in cases where the text is first written using some meter and only later set to music, but as Hayes and Schuh (2019, p. e283) further point out, when a poet-singer improvises verses in some meter but uses completely unrelated rhythms in performance (as some Hausa poets do), this approach implies that they must be able to keep track of two different meters simultaneously. Humans, however, are notoriously bad at attending to conflicting rhythms (e.g., Klapp et al. 1985), making this hypothesis unlikely. Alternatively, the metrical structures of texts and music might correspond in such a way that a position in the poetic meter requiring a stressed syllable, for instance, is aligned with a salient musical beat in performance. This kind of correspondence is found in Tashlhiyt Berber songs, as analyzed by Dell and Elmedlaoui (2008). Finally, it is also possible that the syllabic regularities originate in a historical meter whose rules the poet has adopted as arbitrary conventions instead of productive metrical principles. Clearly, further research is needed in this area of metrics (see also Proto 2015). What is important for the present study is that metrical structures can exist semi-independently from their various oral renditions; this allows us to devise testable hypotheses about the metrical structures of Greek verse without making any conjectures about their intended oral renditions.

### 2.1.3 Jakobson's undulatory curves

Jakobson (1960) theorized that the statistical distribution of linguistically relevant categories (e.g., stresses) in verses created a "regressive undulatory curve" (or a "stratified arrangement") of downbeats and upbeats (pp. 362-363). For example, English and Russian IAMBIC TETRAMETER has eight beats alternating on three intersecting levels: 1) the nuclei and margins of each syllable, 2) upbeats and downbeats of the nuclei, and 3) strong and weak downbeats. The downbeats, in particular the strong ones, more frequently correspond to a stress than do upbeats. Jakobson's undulatory curves are analogous to metrical grids (Liberman 1975; Liberman and Prince 1977; Lerdahl
and Jackendoff 1983), which are widely used to formalize musical meters, linguistic rhythm (e.g., Hayes 1995) as well as poetic meters (e.g., Hayes and Kaun 1996; Hayes and MacEachern 1998; Lerdahl 2001; Dell and Elmedlaoui 2008; Fabb and Halle 2008; Schuh 2011; Hayes and Schuh 2019). In a metrical grid representation, horizontal rows of gridmarks ("x") represent metrical beats (i.e., possible locations of signal onsets), and gridmark columns indicate the metrical strength of each beat; the higher the column, the stronger the beat. Jakobson's analysis of trochaic tetrameters would look as follows using grids:

$$
\begin{array}{cccccccc} 
& & & \mathrm{X} & & & & \mathrm{x}  \tag{1}\\
& \mathrm{X} & & \mathrm{X} & & \mathrm{X} & & \mathrm{X} \\
\mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{x} & \mathrm{X}
\end{array}
$$

The bottom row of gridmarks corresponds to Jakobson's first level of alternation, i.e., that of syllable nuclei and margins, and the second and third to the alternating levels of metrical strength. Thus, the fourth and final syllables of lines in this meter are most expected to be stressed. Jakobson contended that such hierarchic patterns were not "abstract theoretical schemes" (Jakobson 1960, p. 364) nor mere "figures of sound" (p. 367) but linguistic representations that govern not just the alternation of stresses but also the positioning of word and phrase boundaries within lines. As Giuli (1987, p. 33) says, for Jakobson the essence of poetry consists of "recurrent returns" of phonological, syntactic, and semantic patterning where sound organizes meaning but is not an end in itself.

In the generative framework, Jakobson's ideas were first adopted by Halle and Keyser (1966, 1971a, 1971b), who, however, characterized metrical patterns as SERIAL in the sense that they consisted of a linearly ordered sequence of strong and weak metrical positions without any additional structure or constraints on the shape of the pattern (Jespersen 1933 had proposed a similar analysis decades earlier; see also Magnuson and Ryder 1970; Kiparsky 1975). Progress in rhythm research in both linguistics (Liberman 1975; Liberman and Prince 1977) and musicology (e.g., Cooper and Meyer 1971; Lerdahl and Jackendoff 1983) soon outdated the serialist approaches, as it was understood that meter is better described as a hierarchical rhythmic structure, as Jakobson had visioned.

### 2.1.4 Meter as a phonological entity

From a strictly linguistic perspective, the abstract patterns of Jakobson's theory are "probably the most problematic part of the whole theory" Kiparsky (1984, p. 36). One problem is that meter seems to entail the counting of parallel structures (i.e., a line should have the same number of beats as the previous line), something that is unknown in ordinary language-language does not count (e.g., Berwick and Weinberg 1984; McCarthy and Prince 1986). Another problem is that Jakobsonian theory requires matching the text to an external object (i.e., the abstract verse design), a set-up which has no obvious linguistic counterpart either. The counting problem has been solved by treating meters as hierarchical structures, where the number and locations of metrical events are determined by their position in a branching tree (Kiparsky 1977) or metrical grid (Hayes 1984). The matching problem has proved to be more divisive. Some strictly linguistic theories have abandoned the external pattern altogether, striving to represent meter directly in terms of the surface characteristics of verses (e.g., Golston 1998; Golston and Riad 2000, 2005; Fabb and Halle 2008; Riad 2017). Chapter 6 of this dissertation argues against one such approach (Golston and Riad 2000) in some detail. Other linguistic approaches have kept the abstract patterns, conceiving of them as purely linguistic objects (e.g., Blumenfeld 2015). I discuss this hypothesis in §2.2.4.3 below and argue that it is unlikely to be generally true.

The broad metrics paradigm discussed above means abandoning the full separation of poetic and musical meter-but does it also imply that Jakobson's (1960, p. 365) "purely linguistic point of view" to meter should be discarded? At first pass, it would appear so: if the poetic meter of a verse can only be understood in a performance context, it will almost inevitably have some extra-linguistic properties (such as silent beats or syncopated sequences, as will be seen shortly). Yet, in a recent review article on generative metrics, Kiparsky (2020), who does subscribe to the broad view, says that the foundational hypothesis of generative metrics is that meter is a stylization of phonological form whose rhythmic features are grounded in the faculty of language. Or, as he says elsewhere (Kiparsky 2019), poetic meter "superimposes a second layer of rhythmic organization on [the] inherent linguistic rhythm, governed by formally and substantively language-like internalized constraints" (my emphasis). The linguistic hypothesis entails the following conjectures (Kiparsky 2020):
(2) a. Meter inherits from phonology a strict binarity. Ternary meters, ubiquitous in music, are in poetic meter constructed by beat-splitting (Prince 1989; this is explained below in §2.2.4.4).
b. Line lengths are not determined by counting but fall out from a recursively branching binary structure.
c. The hierarchical structure of poetic meter is a stylized counterpart of the Prosodic Hierarchy (i.e., the nested phrasing structure of utterances; e.g., Selkirk 1984; Nespor and Vogel 1989).

On the strictly linguistic view, it makes sense to look for parallels for the ostensibly musical features of verse in ordinary, non-metered language. For example, syncopation (i.e., the reversal of expected metrical emphasis) could be analyzed as analogous to quantitative metathesis in phonology (i.e., the switching of H and L syllables; see, e.g., A. Brown 2018). It has also been suggested that catalexis (i.e., silent beats) is paralleled in ordinary language, manifesting there as empty prosodic constituents (Kiparsky 1991; Kager 1995). Similarly, Selkirk's (1984) "rules of rhythmic euphony" can under certain conditions add (abstract) silent beats to enforce rhythmic alternation in spoken English.

As I argue at some length in this chapter, however, there is reason to believe that poetic meter is not a phonological (or some other linguistic) entity but more likely a cognitive construct similar to that which emerges in music perception. To preview, here are three arguments supporting this view. First, recent psychological and theoretical work in rhythm and meter perception suggests that the hierarchical organization of linguistic, poetic, and musical rhythm is based on shared cognitive principles that are too general to be included in the faculty of language (at least not in the "narrow" sense of the term; see, e.g., Jackendoff 2011). Second, the evidence supporting the conceptualization of poetic meter as a stylization of phonological phrasing is somewhat insecure, as will be seen. And third, there are genuinely ternary poetic meters that apparently cannot be reduced to binarism by beat-splitting, indicating that the binarity hypothesis must be rejected, or at least understood as a tendency instead of a universal rule.

### 2.2 Meter in music, language, and poetry

### 2.2.1 What is rhythm?

The essence of rhythmic processes, in the most abstract and broad sense, is that they contain repeatable sub-processes of a like kind (Simons 2019). By this definition, any process that has a frequency can be called "rhythmic", such as the pulses of a neutron star, the crashing of waves, or the changing of seasons. But from the perspective of auditory rhythm processing, rhythm is the mental transformation of a continuous sound signal into a discrete pattern of events (phenomenally manifested in, e.g., spectral intensity peaks) with relative durations and intervals, similar to how notes are represented in Western music notation (Jones 1976; Fraisse 1982; Honing 2013). The transformation is subject to some temporal constraints. For rhythm to be perceived, the signals should not be too far apart or too close to each other, between about 100 ms and 2 s (Fraisse 1982). In addition, a single rhythmic figure (which includes many rhythmic events) can be maximally $5-6$ seconds long (e.g., Krumhansl 2000), a limit that appears to be related to the span of attention or psychological present (London 2012). ${ }^{3}$ From a broader perspective, rhythm perception is a form of a very basic aspect of human cognition, namely, categorization (Honing 2013; Harnad 2017).

### 2.2.2 Music

When the relative durations of rhythmic sequences are simple (such as $1: 1$ or $1: 2$ ) and repeated, they are likely to be perceived as part of a larger pattern (Jones 1976). The human brain tends to synchronize (or entrain) to such patterns, a process cognitive psychologists call meter perception (Kotz et al. 2018). It is essential to distinguish between the concepts of rhythm and meter (London 2002): while rhythm is a variable pattern of quantized events, meter is a cognitive expectation of rhythmic regularity inferred from and constantly interacting with rhythmic patterns. In music, a prerequisite for the perception of a meter is the extraction of a basic pulse (a.k.a. tactus) from the event stream which is often said to correspond with the speed at which people naturally clap their hands or tap their feet to the rhythmic pattern (e.g., Levitin

[^13]et al. 2018). In addition, meter involves a Prominence hierarchy, meaning that some signals are perceived as "stronger" than others at multiple levels. This hierarchy can also be characterized in terms of simultaneous pulse trains that are in phase with each other, where the coinciding pulses on each pulse train correspond to strong metrical accents (Toiviainen and Snyder 2003, p. 44). Observations of simultaneous phase locking of multiple neural oscillators to rhythmic periodicities give empirical support for the biological basis of metrical structure (for recent reviews, see, e.g., Haegens and Zion Golumbic 2018; Levitin et al. 2018; Schön and Morillon 2018).

### 2.2.2.1 Meter in music

Meter in music is often represented formally using metrical grids (Lerdahl and Jackendoff 1983; §2.1.3 above). As Huron (2006) says, "meter provides a recurring temporal template for coding and predicting event onsets" (p. 198); grids are graphical representations of such templates. Consider the well-known call-and-response tune Shave and a haircut, two bits, which according to Honing (2014, p. 96) is based on the following meter:

| x |  |  |  |  |  |  |  | x |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| x |  |  |  | x |  |  |  | x |  |  |  | x |  |  |
| x |  | x |  | x |  | x |  | x |  | x |  | x |  | x |
| x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x

The tactus of this tune falls on the 2nd or 3rd level counting from the lowest row up, depending on tempo (Rajendran et al. 2018). Either way, there is at least one level of alternating metrical prominence above the tactus; and what makes the tune rhythmically exciting is the short pause between the call and response (haircut . . .two). The pause is heard as a "loud rest" because it corresponds to a prominent position in the metrical hierarchy which should correspond to an onset (Honing 2014, p. 87); in Jakobsonian terms, the missing beat creates a "frustrated expectation" (Jakobson 1960, p. 363).

There are some formal requirements for well-formed grid structures (Lerdahl and Jackendoff 1983, p. 72), such as that every beat on a given level must also be a beat on the level below (a.k.a. the continuous column constraint; Hayes 1995). In addition, there are cognitive constraints on possible grid structures. Most importantly, at each non-terminal level of the hierarchy, there is universally at least one and at most
two spaces between beats (London 2012). The most common meter across cultures is the simplest one possible, that is, one that is binary at all levels (e.g., Brailoiu 1952), with a possible biological basis (e.g., Drake 1993; Pablos Martin et al. 2007); but simple ternary meters such as waltzes are also common. Intriguingly, also anisochronous meters that are popular in Balkan and Bulgarian music appear to be always based on combinations of 2 and 3 (London 2012). Bulgarian songs that count to 7, for instance, are actually metrically $2+2+3$ (Stoyanova 2018), and the same is true of Balkan music (Lerdahl 2001). To offer a few more examples, North Indian jhaptāl music has 10 beats divided into $2+3+2+3$ (Clayton 2010); Japanese haiku poetry which is superficially structured as $5+7+5$ is actually binary $(8+8+8)$ due to a short silence at the end of each line (Kozasa 1997); and the same holds for tanka poetry (Cole and Miyashita 2006) as well as some types of Micronesian verse (Fischer 1959). Traditional Chinese qin music, which is transmitted on a notation that implies free rhythm (and which some scholars have used as an example of music that lacks meter; e.g., Patel 2008), has been argued to be metrically binary by an expert qin musician (Thompson 1997). In sum, although a meter can be non-periodic on the tactus level, periodic alternation nevertheless emerges in larger structures which themselves consist of repetitions of simply binary and ternary sequences.

### 2.2.2.2 Grouping in music

A metrical hierarchy of beats, as Lerdahl and Jackendoff (1983) emphasize, is a continuous cycle of intersecting periodicities without a beginning or an end, and so could also be represented as circles (London 2012) or otherwise geometrically (Honing 2013). ${ }^{4}$ Beginnings and endings only emerge when meter interacts with sequences of eventsor, more specifically, groups of events. Musical grouping structures refer to the perceptual segmentation of a passage of music into chunks, in what is a crucial part of "making sense" of the piece (Lerdahl and Jackendoff 1983, p. 13). Like metrical hierarchies, groups are constructed hierarchically so that larger groups may contain

[^14]smaller ones on multiple levels. As Lerdahl and Jackendoff (1983, p. 36) say, grouping in music is an "auditory analog of the partitioning of the visual field into objects, parts of objects, and parts of parts of objects", and can be accounted for by very general Gestalt principles (Wertheimer 1922) such as similarity and proximity (Jackendoff and Lerdahl 2006; Simon and Winkler 2018). Thus, for instance, consecutive notes in the same pitch, or those separated from other notes by rests, are often perceived as being grouped together. Theories differ as to the details, but the broad principles laid out in Lerdahl and Jackendoff (1983) have been widely accepted in music theory and psychology (e.g., Deliège 1987; Narmour 1990; Cambouropoulos 2001; Temperley 2001).

Both the metrical grid and grouping structures are built up hierarchically, but they differ in one important respect: grouping structures, unlike metrical beats, do not have intrinsic prominence (Lerdahl and Jackendoff 1983, p. 26). The grouping structures interact with the different levels of metrical prominence, so that for instance, when a group begins at some point in the grid that precedes a strong beat, the group is heard as anacrustic (i.e., as being off-beat, or out of phase). To illustrate, consider the well-known melody from the beginning of Mozart's Symphony No. 40 (K. 550), shown in Figure 2.1. Its rhythm, meter, and grouping structure of the melody are illustrated below in (4), (adapted from p. 26).


Figure 2.1: A melody from the beginning of Mozart's Symphony No. 40 (K. 550)
(4)


The recursive structure is built as follows, from top to bottom. First, the entire melody is perceived as a group, indicated by the longest bracket at the bottom. Next, the rest in the middle divides the melody into two distinct groups; and within these groups, it is possible to hear even smaller phrases and motives. How the groups are
perceived depends on various rhythmic and melodic cues, may differ between listeners, and can be ambiguous (as in visual objects where a line serves as a boundary for two adjoining shapes; Jackendoff and Lerdahl 2006). Nevertheless, there are certain formal requirements for group formation (Lerdahl and Jackendoff 1983, p. 37). Most relevant for the present discussion are what can be called a) Exhaustivity: all the events in a group containing subgroups must be grouped; b) COMPLETENESS: a piece constitutes one large group; and c) SEPARATENESS: groups cannot be overlapping. In addition, people tend to perceive groups as symmetrical, so that they contain two subgroups each (p. 49). As pointed out above, the general principles of group segmentation are assumed to follow from basic Gestalt principles, with parallels in vision and auditory scene analysis (Bregman 1990); and just like the musical grouping and metrical structures, hierarchical organization also applies to visual cognition (Palmer 1977; Rosch 2002; Jackendoff 2009, etc.) and even complex human actions (Jackendoff 2007). For more examples of grouping as a shared cognitive process, see Patel (2008, pp. 106-112).

To sum up this section: rhythm is a manifestation of the human drive to categorize and, in the auditory modality, a pattern of discretely perceived ratios of durations. Musical meter is an anticipatory mental model of future rhythmic patterns and involves a hierarchic organization of beats with multiple intersecting levels of prominence, one of which - the tactus level-stands out as the most salient. Metrical patterns tend to be rhythmically simple, either based on the ratio 1:1 (duple meters) or 1:2 (triple meters) or some combination of these; and are by definition cyclic at some level of the beat hierarchy (London 2012, p. 191). Moreover, humans perceive musical sequences as recursive grouping structures, with clear parallels in other cognitive domains.

### 2.2.3 Language

It is commonplace that language is rhythmic, manifesting in features such as stress, syllable weight, and phrasing, and their semi-regular organization in ordinary speech. But the apparent triviality of linguistic rhythm is deceiving: on the definition of rhythm worked out above ( $\S 2.2 .1$ ), that is, as a pattern of perceived durations contrasted by simple integer ratios, linguistic rhythm is in a sense nothing more than a metaphor (Nolan and Jeon 2014). Ordinary speech, as much research has shown (see Haegens and Zion Golumbic 2018 for a review), is far from having simple equal-timed rhythmic relations; and Lehiste's (1977) hypothesis that rhythm in language is nevertheless per-
ceptually isochronous has never been corroborated by empirical evidence (Patel 2008; Turk and Shattuck-Hufnagel 2013). It then appears that to talk about rhythm in language, we need a different definition. Nolan and Jeon (2014) argue that linguistic rhythm is contrastive in the sense that it consists of elements contrasting only in relative prominence (e.g., stressed vs. unstressed, L vs. H syllables) instead of discrete durational ratios (coordinative rhythm).

### 2.2.3.1 Meter in language

An influential theoretical approach to linguistic rhythm called Metrical Phonology (Liberman and Prince 1977; Selkirk 1984; Hayes 1995) treats linguistic rhythm as a hierarchic pattern of prominence, formally homologous to that used to represent musical meter, but in abstract instead of phenomenal time. According to it, different levels on a hierarchy represent incrementally greater levels of prominence in an utterance, corresponding to secondary and primary stresses, phrasal stresses, etc., until the most prominent element of the entire utterance. Thus the full intonational rhythmic pattern of the phrase Twenty-seven Mississippi legislators can be represented as follows (Hayes 1995, p. 28):

| X | X |  |  |  | X |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  |  | X |  |  |  |
| X |  | X |  | X |  | X |  | X |  | X |  |
| X | X | X | X | X | X | X | X | X | X | X | X |

Twen- ty- se- ven Mis- sis- sip- pi leg- is- lat- ors

In addition to being hierarchically organized, linguistic rhythm shares with musical rhythm a cross-linguistic (but not universal) tendency to be alternating, embodied, for instance, in the phonological rule known from a number of languages that moves a stress when it would clash with another one in a phrase (Liberman and Prince 1977; Nespor 1990), as well as in languages with alternating stress systems (e.g., Hayes 1995; Kager 2007).

However, as Patel (2008, p. 141) says, the phonological-metrical grids and musical grids, despite their formal homology, represent different things. First, an essential property of metrical grids in music is the equidistant spacing of beats (Lerdahl and Jackendoff 1983, p. 19), representing rhythmic periodicity. Phonological grids, which lack the implication of periodic rhythm, have no such requirement. Second, musical rhythm hierarchies, as representations of attentional expectations, can be mentally up-
held even when phenomenal rhythms conflict with it; and it is doubtful that speech rhythm can create such a stable framework of anticipation (though there is some evidence for entrainment to speech rhythms; see Haegens and Zion Golumbic 2018 for a review). Third, and most importantly, unlike phonological grids, the metrical grids of music need not be in one-to-one correspondence with notes, as when a note is stretched out across multiple beats (see also Jackendoff 2009). In short, metrical phonological grids are maps of the prominence structures of individual phrases, but musical grids are abstract mental anticipatory models that interact with phenomenal rhythms.

Patel (2008, p. 142) further points out that the principles that appear to produce rhythmic alternation in music and speech may be due to different mechanisms. For instance, it is possible to describe what appears to be rhythmic alternation simply as an avoidance to cluster stresses too close together (Nespor and Vogel 1989; Nespor 1990; Kager 2007). Clash avoidance, in turn, may ultimately have a functional explanation such as articulatory ease. Overall, one cannot rule out the possibility that "linguistic rhythm is the product of a variety of interacting phonological phenomena, and not an organizing principle, unlike the case of music" (Patel 2008, p. 177). Finally, it must be noted that even under the contrastive definition of rhythm, the metrical structures of language are rarely regular. For instance, many languages have unpredictable stress patterns, and even languages with alternating word-level stress do not normally have any metrical regularity in larger phrases (e.g., van der Hulst 2014) or even at the level of morphological constituency (Baker 2014).

### 2.2.3.2 Grouping in language

Like musical sequences, linguistic utterances are grouped recursively. In this context, what is meant is not syntax (i.e., the hierarchic relations among words that code meaning), but the grouping of speech sequences into temporal units. The mainstream theoretical framework in linguistics for auditory grouping is the theory of Prosodic Hierarchy (Selkirk 1984; Nespor and Vogel 1989; Hayes 1989b), which describes the mapping from syntactic constituents to mentally represented groups of linguistic phrasing, and further, the mapping from these representations to pronunciation. Besides syntax, grouping structures of utterances are shaped by other factors such as information structure and affect (e.g., Shattuck-Hufnagel and Turk 1996), and so there are many possible grouping structures for phrases, just like there are for musical groups. Another property that prosodic and musical groups share is that the groups cannot
be partially overlapping, and that every complete utterance belongs to a single group enclosing all the other groups in the hierarchy (Katz 2018).

Musical and phonological groups differ, however, in a number of ways. The most important difference may be that whereas musical groups and musical grids are separate (see $\S 2.2 .4 .3$ above), phonological grids and phrases are commonly assumed to be tightly affiliated in that each non-terminal gridmark "heads" some prosodic phrase (e.g., Hayes 1995). The principle of culminativity further requires that lexical words have "a unique and obligatory stressed syllable and all prosodic constituents to have a unique and obligatory head" (Féry 2017, p. 318), which means that the metrical structure of an utterance can be derived from its grouping hierarchy. Consider again the phrase Twenty-seven Mississippi legislators, now annotated with the grouping structure using parentheses:


Twen- ty- se- ven Mis- sis- sip- pi leg- is- lat- ors

As can be seen, every constituent above the syllable has exactly one gridmark acting as its head. Hayes (1995, p. 41) calls this the Faithfulness condition: "Gridmarks must be in one-to-one correspondence with the domains that contain them". The view that gridmarks function as heads of prosodic categories has been accepted as the mainstream view in phonology (Myrberg and Riad 2016). In musical structures, by contrast, groups are not required to be headed-musical groups are recursive, but musical grids are not (Jackendoff 2011). In other words, unlike linguistic utterances, musical pieces are not culminative.

Another major difference between musical and prosodic grouping structures is that the latter consist of distinct types of groups. There is no consensus on the required number and labeling of the groups, but commonly included categories include the syllable, foot, phonological word, phonological phrase and utterance (e.g., Kiparsky 2020). In (6) the first four groups correspond to those shown in the gridmark rows 1-4. Interestingly, as Scheer (2011, p. 315) points out, the categories in standard Prosodic Hierarchy theory are heterogeneous phonological objects: only two of the lowest categories (syllable and foot) are purely phonological and constructed bottom-up, whereas the higher
categories are the product of top-down mapping rules incorporating non-phonological (e.g., syntactic) information. Hence, the derivation of the grid also depends on heterogeneous rhythmic principles, the lowest levels being determined by the language's phonological grammar and the higher levels on more variable factors such as intonation (Ladd 2008). Indeed Hayes (1989b, p. 207) argues that the word should be the lowest level in the prosodic hierarchy; for similar views see, e.g., Inkelas (1989), Downing (2006), and Steedman (2014).

### 2.2.4 Poetic meter

It is time to return to poetic meter. As has already been said, most work in generative metrics characterizes meter in poetry as a system of correspondence between an abstract rhythmic pattern and its surface instantiations as verses. The correspondence is formalized in terms of a "metrical grammar", a system of rules or constraints which evaluates the metrical well-formedness of a given linguistic passage with regard to the underlying pattern (this is discussed in more detail in Chapter 3). Thus, metrical analysis in this framework involves studying two separate components, namely, the metrical pattern and the metrical grammar (Halle and Keyser 1971a, p. 140).

Much work in generative metrics further assumes that both the abstract pattern and the grammar should be analyzed in purely linguistic terms: "the metrical templates are built of the same material as ordinary prosodic structure" (Blumenfeld 2016, p. 419), and the metrical grammar consists of "language-like internalized constraints" (Kiparsky 2019). In this chapter, I demonstrate that although the linguistic hypothesis may be borne out by some types of literary art verse (Schuh 2011, p. 225), it does not seem to be generally true.

### 2.2.4.1 Recursion in poetic meter

The abstract metrical pattern is, like the prosodic hierarchy, commonly represented as a recursive hierarchy of headed constituents. As such, it can (and has been) visualized using either a combination of grids and groups (e.g., Hayes 1983, 1989b; Schuh 2011; Blumenfeld 2015) or a labeled tree representation (e.g., Kiparsky 1977; Prince 1989; Youmans 1989; Kiparsky 2018). The two are usually thought to be formally
equivalent. ${ }^{5}$ For example, Kiparsky (2020) visualizes a hypothetical 16-position binary branching meter using trees and bracketed grids as shown in (7).


The assumed recursive structure provides a solution to the counting problem (see §2.1.4 above): if meters are hierarchic structures, there is no need to count the number of metrical positions or feet in lines, since their number falls out from the hierarchy. However, as pointed out in $\S 2.2 .2$, recursion is also a central property of music perception and other cognitive processes, and so its presence in poetic meter is not as such evidence for the linguistic hypothesis of metrics. A related argument for the linguistic analysis of metrical templates has been that the templates appear to be binary at all levels (Kiparsky 2020); but as will be demonstrated shortly (§2.2.4.4), genuinely ternary poetic meters do exist.

### 2.2.4.2 Quantitative meter

Let us now see how quantitative meters can be analyzed using metrical grids, following previous work such as Schuh (2011) and Hayes and Schuh (2019). Recall first that in the metrical grid representation, the grid must include a gridmark row for all possible signal onsets (§2.2.2). In the linguistic setting, this level corresponds to syllables, meaning that all syllables in a line of verse must be able to map to at least one

[^15]gridmark in the grid representation. Note then that under the moraic theory (see §1.3.1.1) H syllables are twice as "long" as L (in the abstract, or contrastive sense), and so we can use gridmark columns straightforwardly to represent moras, so that L (normally) consumes one and H two columns from the grid. This much constitutes the basic durational mapping of mora-based meter. But because meter also involves, by definition, alternating prominences at some level of the hierarchy, we need at least two rows of gridmarks. A well-established fact about rhythm perception is that humans tend to perceive longer sounds as more prominent than shorter sounds (e.g., Fraisse 1982, p. 162); in language, this manifests in the well-known generalization that heavy syllables attract linguistic stress (Prince 1990). Therefore, it makes sense to construct grids for quantitative meter such that the second row of gridmarks represents positions that tend to correspond to the left edges of H syllables. The wording "tend to" should be emphasized, because on the theory followed here (§2.1.3), the metrical grid is an abstraction and does not need to map one-to-one to the actual surface sequences of verses. (A phonological grid, by contrast, would always map H syllables to Strong positions; see §2.2.3.1 above). Additionally, a quantitative metrical grid may have higher levels of prominence, indicating stricter requirements for initiating H syllables in the more prominent positions.

To illustrate, Hayes and Schuh (2019) analyze the Hausa rajaz meter using a grid with six positions, each corresponding to a mora. They note that the metra must always have six moras and have the syllabic pattern LHLH, HHH, HLLH, or LLHH, or exceptionally HHLH, which has seven moras. ${ }^{6}$ Based on the frequencies of the different patterns, they construct the grid and alignments as shown in (8).

| x |  |  | x |
| :---: | :---: | :---: | :---: |
| x | x x | x | x |
| L | H | L | H |
| H | L | L | H |
|  | L H |  | H |
| H | H |  | H |

LHLH is the most straightforward of the allowed variants: both Hs are mapped to strong positions, and the moras map one-to-one to the grid. The next variant, HLLH

[^16]has an initial syncopation: the mora count and syllable types are kept intact, but the mora starts with HL instead of LH, causing the first strong beat to be carried over without being mapped to a signal onset. The LLHH-variant has another type of syncopation where a prominent H syllable initiates in a weak beat right after the first strong one. Third, the variant HHH combines both syncopations in what can be analyzed as a hemiola, the mapping of three prominent syllables against two strong beats. And finally, every pattern ends invariably in H , reflecting the highest metrical strength at the corresponding position. It is important to emphasize that the hexamoraic rajaz metron is a textual meter: Hausa poets sing rajaz-based tunes in different rhythmic renditions (and even using different measures) from the simple structure shown in (8). As Hayes and Schuh (2019, p. e262, footnote 11) point out, on their analysis the rajaz meter would have to be considered "very dubious" if taken as a purely linguistic object. Arguably, the existence of the syncopated variants also suggests that the textual meter must involve some notion of temporal periodicity absent from the regular speech of Hausa.

As pointed out in §2.1.2 above, many types of poetic meter cannot be adequately described without taking into account silent beats (i.e., rests) in performance. But if L and H syllables correspond to one and two moras, respectively, the theory of moras says nothing about silence. Evidently, once the positions of the metrical grid are allowed to be unaligned with any phonological material (i.e., "empty"), the grid itself cannot help but be somehow related to the temporal manifestation of the pattern, and so be something other than abstractly phonological.

There is some relevant anecdotal evidence about how poets themselves understand metrical rhythm. For instance, the 19th century English poet Gerald Manley Hopkins says (as quoted by Jakobson 1960, p. 366) that in his poems "two rhythms are in some manner running at once", evidently referring to the interplay between an invariant template and its surface variants (see also Hayes and Moore-Cantwell 2011, p. 237). The wording suggests that for Hopkins, the template is not just an abstract configurational pattern but a rhythmic representation, just like musical meter. Two further anecdotes illuminate the role of the template in sung poetry. First, according to Schuh (2011, p. 226) Hausa poets compose new lines of poetry by singing them to an appropriate tune; in this case the musical and textual meters are often nearly identical. A second example comes from Tashlhiyt Berber songs, where, by contrast, the textual meter and musical meters are distinct (Dell and Elmedlaoui 2008). In that tradition, poets make
sense of the textual meter by intuitively producing a sequence of nonsense syllables (i.e., vocables) like a lay da la la lay da lay da la l[i] (ibid., p. 31) using a narrow set of phonemes (e.g., only /a/ and /i/ nuclei). Underlying such "lalay-formulas" (as well as actual verses) must clearly be some rhythmic pattern, since the vocable sequences are nothing if not figures of sound.

Finally, the idea that metrical patterns are phonological entities is undermined by the fact that alternating meters can exist without a linguistic basis. For example, French does not have a contrastive stress, but does nevertheless have alternating rhythms in music and poetry (Biggs 1996; Temperley and Temperley 2013; Dell 2015). It is, of course, possible to explain this by hypothesizing that metrical structure is a part of the linguistic faculty and so is potentially present in all languages (and poetic meters). But as we have seen, hierarchic and recursive cognitive structures are not unique to language.

### 2.2.4.3 Grouping in poetic meter

Following Hayes (1989b), grouping in poetic meter can be understood in two ways. The first meaning relates to the basic periodicity of verse rhythm. For instance, the English iambic pentameter can be alternatively described as a flat sequence of ten positions, every other one of which is metrically prominent (Halle and Keyser 1966); or it can be described as a sequence of five feet, each with one up- and downbeat (e.g., Attridge 1996). The foot as a minimal perceptual unit of rhythm is well studied experimentally (see Iversen et al. 2008, for references) and is as old as ancient rhythm theory (see, e.g., Marchetti 2009, p. 146-157). Psychological research in rhythm has also found that humans group identical signals in a hierarchic fashion, so that not only feet are perceived in undifferentiated sequences but also groups of feet (Devine and Stephens 1994, p. 91).

The other sense of grouping is to posit it as an inherent part of the metrical pattern, responsible for the regularities in the phrasing of individual verses (e.g., Jakobson 1960; Hayes 1989b). The reality of such grouping is most evident at the level of the line itself: across languages, poets try to match line breaks with phonological group boundaries. It has also been argued that meters define hierarchic subgroups within lines (i.e., metra, cola, feet, etc.), which are matched by phonological phrases; but evidence for these lineinternal groups tends to be more blurry than for the line level. For example, poets using the English iambic pentameter appear to use two different structures, the one having a
$2+3$ colon structure and the other $3+2$ (Youmans 1989). For a more complex example, the Greek dactylic hexameter has three regular "areas" for word-end, but there are several possibilities as to where the phrase boundaries may fall (Barnes 1986). The smallest unit in verse, the metrical foot, is most controversial as a phrasal group (see, e.g., Attridge 1996; Van Oostendorp 2017 for critical remarks). According to Hayes et al. (2012) feet are modestly "echoed" by phrasal groups in Shakespeare and Milton; see also Kiparsky (1977) for evidence of feet in English meters.

In an influential paper, Hayes (1989b) conjectured that the grouping structures in poetic meter are closely parallel to the categories in the Prosodic Hierarchy (see $\S 2.2 .3 .2)$. A crucial observation that supports the hypothesis is that across traditions, metrical rules (or constraints) appear to refer to the domains and edges of phonological phrases instead of syntactic ones, and that the strictness of the rules tends to correlate with the level of the grouping (Hayes 1989b). For instance, Hayes et al. (2012, p. 722) found that in English iambic pentameters, the higher the level of the phonological group, the more it is favored at foot and in particular at line boundaries, and vice versa. Similar hierarchical "bracketing" effects have been observed in other traditions, such as Serbo-Croatian, (Jakobson 1979) Finnish (Kiparsky 1968) and Italian (Helsloot 1995). In addition to phrase boundaries, the metrical-prosodic hierarchy has been said to account for the intersecting periodicities of verse, in the sense that the heads of the metrical constituents demand stressed (or heavy) syllables more often than nonheads (Hayes 1989b). However, such effects can also be invoked without positing a constituent structure, as Hayes (1983) has argued.

A number of later studies took a step further with regard to the parallelism between metrical and prosodic structures, making the assumption that the metrical hierarchy is a form of prosodic structure, only without segmental content (e.g., Golston and Riad 2000; Blumenfeld 2015; Riad 2017; Kiparsky 2019, 2020). On this view, the traditional categories in the metrical hierarchy (foot, metron, etc.) are nothing but figurative names for the phonological categories, with which they are equivalent. The equivalences, however, may differ between analyses and traditions; Table 2.2 shows previous proposals for Greek and English (Int=Intonational phrase, $\mathrm{Ph}=$ Phonological phrase, $\mathrm{PhWd}=$ Phonological word, $\mathrm{PhFt}=$ Phonological foot).

|  |  | Prosodic Hierarchy |  |  |
| :--- | :--- | :--- | :--- | :--- |
| Level | Metrical hierarchy | Greek $^{7}$ | English $^{8}$ | English $^{9}$ |
| 4 | Line | Int | Int | Ph |
| 3 | Dipody, half-line, colon | Ph | Ph | PhWd |
| 2 | Verse foot | PhWd | PrWd | PhFt |
| 1 | Metrical position | PhFt | syllable | syllable |
| 0 | mora | mora |  | mora |

Table 2.2: Proposed phonological equivalents of metrical categories

A potential source of evidence for the category equivalences is phrasing that matches with the corresponding metrical group. For instance, assuming that the English iambic pentameter contains five verse feet, according to Blumenfeld (2015) there should ideally be five phonological feet per line. As noted above, though poets generally do place phrasal boundaries at line-ends, there is little evidence that English poets normally "echo" verse feet with phonological feet; indeed the opposite is often true, as Van Oostendorp (2017) points out. This is not to say that feet do not exist: as Hayes et al. (2012) show, Milton and Shakespeare tend to align intonational and phonological phrase breaks with foot boundaries. But surely verse feet cannot be equated with intonational or phonological phrases, for what would the higher metrical categories in that case be equal to?

On the principle of culminativity (§2.2.3.2), the prosodic-metrical hierarchy hypothesis entails that not only the grouping structures but also the metrical grid structure must be recursive. Accordingly, poetic meter must have a single prominence peak, such as in (7) above. This is in contrast to musical grids (§2.2.2), which only go up to a small number of levels (Jackendoff 2011). A review of previous metrical work reveals, however, that there is not much evidence for culminativity in metrical hierarchies similar to that in ordinary speech. Instead, metrical hierarchies appear to be more akin to the "flat" periodicities of musical meter. For instance, in quantitative meters, only two levels of metrical strength are relevant in the meters of Hausa (Hayes and Schuh

[^17]2019), Tashlhiyt Berber (Dell and Elmedlaoui 2008), Arabic (Deo and Kiparsky 2011) and Sanskrit (Deo 2007). According to Proto and Dell (2013), stress-based meters universally have just one (or at the very most, two) levels of metrical strength. A possible linguistic explanation would be that the metrical hierarchy is prosodically underspecified (as in Blumenfeld 2015, p. 90), but it seems simpler to assume that the prominence structure is like that in music, especially in the light of the other shared properties of musical and poetic meters.

The ancient Greek metrical system offers a further argument against the prosodicmetrical hierarchy hypothesis. In Chapter 4 I will argue that the basic building block of the Greek iambic meters is the grid shown in (9) below. Note that the grid is the same as that proposed by Hayes and Schuh (2019) for the Hausa rajaz metron.

|  |  |  |  |  |  | $x$ |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | x |  |  |  | x |  |  |
| $\ldots$ | x | x | x | x | x | $\ldots$ |  |

The implied grouping structure - on the principle of culminativity-is shown in (10). The smaller grouping level is, of course, the foot and the larger one is traditionally called an iambic metron.


Notoriously (Hayes and Schuh 2015), Greek poets generally avoid matching the "natural" grouping structures of the meter with phonological phrases. In iambic trimeter, which consists of three iambic metra, word-ends are banned from the end of the first two metra, but required right after the first gridmark of the second or third metron. Here, then, the analysis seems to require the separation of grids and grouping structures, just as Lerdahl and Jackendoff (1983) argue for musical structure. Other Greek meters behave similarly: in the hexameter, for instance, lines are required to have caesuras in the middle of metrical cycles, indicating that constituency is here, too, independent from meter.

Finally, in light of the above observations, it is interesting to repeat the point made above (§2.2.3.2) that the Prosodic Hierarchy theory should perhaps not include the bottom-up levels at all (i.e., mora, syllable, foot; see Scheer 2011, p. 341). If it is true that poetic meter underlyingly specifies just two or three layers of alternation
(see above), what meter may ultimately be left with are just the levels that should be excluded from the prosodic hierarchy.

### 2.2.4.4 Against binarism in poetic metrics

This section addresses the hypothesis that poetic meters inherit from phonology a strict binarity (Prince 1989). It is widely thought that phonology cannot count past two (e.g., McCarthy and Prince 1986; Kenstowicz 1994; Downing 2006), a well-known example being word stress: in a large class of languages, stress occurs on every other syllable (Liberman 1975; Liberman and Prince 1977; Prince 1983; Kager 2007) but only a handful of languages have ternary stress. ${ }^{10}$ Another example is reduplication, a process where new words are formed by copying a part of the base word. The copied element typically respects binarity by being maximally bimoraic or bisyllabic (McCarthy and Prince 1986). Thirdly, the vast majority of languages that have syllable weight-based processes treat weight on a binary scale, that is, as L or H (Gordon 2007).

A prosodic or metrical structure can be binary in two respects: 1) by having a metrical grid that is binary at each level of the hierarchy, or 2) by having a binarily branching grouping structure. Assuming the STRICT LAYER HYPOTHESIS, according to which any given level in the hierarchy consists exclusively of groups in the next lower level (Selkirk 1984), a binary grid always implies a binary grouping, and vice versa (see also §2.2.3.2). The relationship between grids and trees gets more complicated, however, if layer "skipping" and recursion are allowed (and much recent linguistic work argues they should be; for references see, e.g., Myrberg and Riad 2016, p. 447). Most importantly for the present discussion, these properties make it possible to formulate trees that do not map to binary metrical grids. For example, Kiparsky (2020) analyzes Shakespeare's early iambic pentameters as shown in (11).

[^18](11)


In the proposed metrical tree analysis, all constituents branch twice: this is achieved on account of layer skipping (i.e., the skipped left branch of the highest node and that of the topmost S). But if we translate the tree structure into an equivalent grid representation, we can see that the structure is actually non-binary:

$$
\begin{array}{cccccccccc} 
& & & & & & & & &  \tag{12}\\
& & & \mathrm{X} & & & & & & \\
& \mathrm{X} & & \mathrm{X} & & \mathrm{X} & & \mathrm{X} & & \mathrm{X} \\
\mathrm{X} \\
\mathrm{x} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} \\
\mathrm{X}
\end{array}
$$

Indeed, there appears to be no motivation for the binary tree-based analysis other than the hypothetical binarism of metrics itself; nor is it obvious what kind of evidence would support (11) over ternary alternatives, such as the following:


Another way to analyze ternary rhythms as underlyingly binary is by beatSplitting (Prince 1989). On the face of it, ternary poetic meters appear to be quite common across traditions: anapestic rhythms (i.e., ...WWS WWS WWS...), for instance, are common in English, Finnish, French, and Russian poetry (among others). However, Prince (ibid., pp. 52-55) argues (following Kiparsky 1977) that the WW sequence in such ostensibly ternary rhythms is in fact a SW-structure branching from a split W:

Anapest (WWS)


Dactyl (SWW)


The beat-splitting analysis is based on Prince's idea that metrical positions (i.e., the Ws and Ss that normally correspond to a syllable) are analogous to the tactus beats of music, which, when subdivided, must branch to SW instead of WS or WW in order to be well-formed (Lerdahl and Jackendoff 1983, p. 72). This becomes evident if we again translate the trees into grids: ${ }^{11}$

$$
\begin{array}{cccc} 
& & & \mathrm{X}  \tag{15}\\
& & \\
\mathrm{X} & & \mathrm{X} & \\
\mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X}
\end{array}
$$

X
$\mathrm{X} \quad \mathrm{X}$
X X X X

As can be inferred from above, if the subdivisions were WW, a rhythmic lapse would result (three consecutive gridmarks without a strong beat); and both WS and SS would produce clashes (a strong beat next to another one). The SW organization of the split beats is also supported by empirical evidence from a number of Russian and English meters, where the syllables corresponding to the first $S$ of the subdivided beat are subject to the same rules as the undivided S beats (Kiparsky 1975, 1977; Prince 1989).

But the above examples are not the only possible ternary rhythms in poetic meter. Consider, for instance, a dactyl where the S beat (instead of W ) is split:
(16) Dactyl (SWW)


[^19]According to Kiparsky (1977), there is an abundance of Swedish, Finnish and German poetry that is characterized by dactyls as shown in (16) instead of the W-branching version of (14). Similarly, Deo and Kiparsky (2011) analyze the Persian ruba'i meter using anapestic feet with the following structure:
(17) Anapest


Again, compare (17) with the anapest in (14), where it was the W beat that was split and organized as SW. All of the structures shown thus far are binary in the tree representation, by virtue of branchingness. But once the same structures are represented using grids, it will immediately become clear that the structures shown in (16) and (17) cannot be binary. Consider first a straightforward grid representation of the dactyl in (16), where both the divided MP and the undivided MP again correspond to two grid marks:

```
x
x x x x
```

As can be seen, the transformation produces a grid with three consecutive weak gridmarks, in violation of basic Lerdahl-Jackendovian metrical well-formedness (1983, p. 72). The grid could be fixed by adding a strong gridmark in the third position; but this would no longer accurately represent this type of poetry, as analyzed by Kiparsky (1977). In fact, the rhythm cannot be anything else than ternary:

```
x
x x x
```

The same argument is valid for the anapestic foot in (17), mutatis mutandis. It then appears that beat-splitting cannot rescue all of poetic metrics from ternarity.

Furthermore, meters can easily be ternary at the moraic level. As noted above (§2.2.4.2), Hausa and Greek iambic meters can be analyzed using a metrical grid where each phonological mora normally corresponds to a gridmark. The basic metrical pattern is in both cases the following:

$$
\begin{array}{lllllll} 
& \mathrm{X} & & & \mathrm{X} & &  \tag{20}\\
\ldots \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \ldots
\end{array}
$$

Prince (1989) analyzes such structures using MPs, with the requirement that strong MPs contain two phonological moras and weak positions at least one. This reduces the ternary moraic rhythm to a binary alternation of MPs, but it comes at a cost. Particularly problematic is Prince's (ibid., p. 55) assumption that MPs are analogous to musical tactus beats. Namely, it suggests that MPs that are invariably monomoraic ( $\checkmark$ in traditional notation) either 1) cause rhythmic clashes at the tactus level (since $\checkmark$ corresponds to a single grid column), or 2 ) require the obligatory light syllables to be "stretched" in order to fill the usual length of the tactus beat and make the pattern rhythmic. It seems more plausible to assume that it is the $S$ positions that are analogous to tactus beats, and that the W positions correspond durationally to some subdivision of S. This is exactly how Hausa poets sing structures like (20) (Schuh 2011), offering empirical support for the ternary grid-based analysis.

### 2.3 Summing up

This chapter focused on the nature of poetic meter, a subject of continuing debate among metrists. Two competing generative theories were pitted against each other: 1) a purely linguistic theory that seeks to abolish any extra-linguistic ingredients from metrical analysis, and 2) an account that would treat poetic meter as an essentially musical phenomenon. As I tried to show, the meter-as-language theory faces a number of theoretical and empirical challenges that the meter-as-music theory seems to avoid. Most importantly, previous research has demonstrated that meters sometimes cannot be understood without taking into account such evidently musical properties as silent beats and syncopation, which have no well-known linguistic counterparts. Furthermore, though in some forms of sung poetry the textual patterns have been shown to possess an inherent metrical structure semi-independent of their musical rendition, even the purely textual meters differ in many ways from the rhythmic patterning of ordinary speech. The idea that poetic meter may exist as a rhythmic abstraction specific to textual patterns is here important, as it provides motivation to seek explanations for the metrical choices of ancient Greek poets even in the absence of evidence about textsetting.

## Chapter 3

## Probabilistic metrics using Maxent

A central goal generative metrics is to explicitly characterize the metrical intuitions of poets. This chapter discusses a probabilistic approach to this challenge using a statistical method called Maximum entropy modeling (Maxent). Assuming that poets who write in meter generally prefer rhythmically well-formed lines over more complex ones, the frequencies of different line types in a corpus can be modeled based on the extent to which they obey basic rules of rhythmic well-formedness. As I discuss, Maxent models are based on the principle of choosing the simplest possible analysis subject to the information given, and are therefore justified as a heuristic means for finding meaningful generalizations. The method presented here follows previous work in Maxent metrics (Hayes and Moore-Cantwell 2011; Hayes et al. 2012; Hayes and Schuh 2019) and extends it by introducing a novel way to assess the intentionality of metrical features against the backdrop of lexical statistics. After introducing and discussing the Maxent modeling procedures, I formulate a set of rhythmic constraints for the analysis of ancient Greek mora-based meters.

### 3.1 Metrical well-formedness

The previous chapter sketched a generative theory of meter, a core idea of which is that metrical composition is governed by an underlying metrical scheme that poets try to "evoke" (Hayes et al. 2012, p. 697) using phonological material. This chapter focuses on the problem of explaining why poets accept only certain phonological patterns as
legal manifestations of a meter, and why they prefer to use some patterns more often than others. In short, the goal is
(1) to model poets' knowledge of degrees of metrical acceptability of phonological structures, including distinctions that are greater than binary. ${ }^{1}$

The following sections look at how this challenge can be met by devising probabilistic models of poets' metrical practice. Following recent work in metrics (e.g., Hayes and Moore-Cantwell 2011; Hayes et al. 2012; Hayes and Schuh 2019), I employ the models in the framework of Maxent grammar (Goldwater and Johnson 2003; Hayes and Wilson 2008), which will be discussed in some detail in this chapter.

### 3.1.1 Halle and Keyser's frequency hypothesis

In a foundational paper of generative metrics, Halle and Keyser (1971a) say that metrical analysis should start from the assumption that poets have intuitive beliefs about the validity of different rhythmical patterns as instantiations of a given meter. Throughout metrical traditions, including Greek, poets do not normally use exactly the same rhythmic pattern line after line, but vary the rhythm within an allowable range. ${ }^{2}$ Halle and Keyser's idea is that the metricality beliefs of poets can be inferred by observing the frequencies of different patterns in a text corpus: simply, the more frequently a pattern is used, the more metrically well-formed it is; or conversely, "the more complex the line in terms of [the analysis], the less frequently it occurs" (p. 157). I adopt this so-called FREQUENCY HYPOTHESIS in this dissertation, following much previous work including Kiparsky (1977), Golston and Riad (2000), Hayes et al. (2012), and Hayes and Schuh (2019).

By characterizing metrical corpora in terms of metrical constraints, the METRICAL COMPLEXITY (i.e., the inverse of metrical well-formedness) of each invididual line becomes a matter of the degree to which it violates such constraints. (Which particular constraints are used is a theoretical choice of the analyst; I introduce a small set of constraints for quantitative metrics below in §3.4.) This introduces the possibility of

[^20]modeling the metrical well-formedness intuitions of poets in terms of constraint violations: let the metrical corpus under scrutiny be a random sample from an unknown PROBABILITY DISTRIBUTION, and we can use statistical methods to estimate that distribution, given the constraint violations. The idea that a "metrical grammar" can so be used to predict the frequencies of different line types is essentially a probabilistic update of the frequency hypothesis (Hayes 2013, p. 4).

### 3.2 Background: constraint-based metrics

Generative metrics has used constraints (i.e., conditions of metrical well-formedness) since the foundational work of Halle and Keyser (Halle and Keyser 1966, 1971a, 1971b). In early work, however, constraints determined the absolute conditions under which patterns were legal instantiations of a meter (e.g., Halle and Keyser 1966). It was soon recognized that such "hard" constraints are inadequate for describing the metrical variation that abounds in nearly all metrical traditions, and so the focus shifted to metrical preferences (see Youmans 1983 for a review). It was also understood early that metrical analysis should be non-derivational, in the sense that in the matching between meter and its surface manifestations "nothing changes into anything else" (Kiparsky 1977, p. 235). ${ }^{3}$ Interestingly, by being constraint-based from the outset, generative metrical analysis has anticipated the development of Optimality Theory (OT; Prince and Smolensky 2004), which analyzes linguistic forms as emerging from the interaction of violable preferences. ${ }^{4}$

### 3.2.1 An example

As an illustration, consider lines 1-3 of Shakespeare's Twelfth Night. First, let us scan the stress patterns of these lines using the traditional notation of "/" for stressed and "-" unstressed syllables. (2) shows my scansion of the lines.
(2) If music be the food of love, play on; - / - / - / - / - / give me excess of it, that, surfeiting / - - / - - - / - the appetite may sicken and so die. - / - - $/$ - - - /

[^21]As can be seen, each line has a different rhythmic profile: in the first line, every other syllable is stressed; the second line starts with a stress followed by what looks like an irregular pattern; and the third one is rhythmically similar to the first line, though it has fewer stresses. Despite the rhythmic variability here and elsewhere in Shakespeare's iambic pentameters, most speakers of English can intuitively induce the basic metrical scheme that underlies them. Using a metrical grid representation (see $\S 2.1 .3)$, the pattern is as follows:

$$
\begin{array}{cccccccccc} 
& \mathrm{X} & & \mathrm{X} & & \mathrm{X} & & \mathrm{X} & & \mathrm{x}  \tag{3}\\
\mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X}
\end{array}
$$

Assuming that something like (3) correctly represents the basic rhythms of Shakespeare's iambic pentameters, the metrist's task is to explain 1) why only some prosodic patterns are found in Shakespeare's works, and 2) why some appear more often than others.

For illustration, let us now construct a (shamelessly simplified) metrical grammar of Shakespeare's iambic pentameters, using just two constraints. It was noted above that the line give me excess of it, that, surfeiting feels intuitively rhythmically more complex than the other two shown in (2). Suppose (following Halle and Keyser 1971a) that the complexity is in part due to a violation of a constraint that tells the poet to avoid putting a stressed syllable in a W position; this preference may be formulated as the constraint WEAK $\Rightarrow$ UnStressed. Because the iambic pattern in (3) starts with a weak gridmark, the line-initial stressed word give violates WEAK $\Rightarrow$ UnSTRESSED once.

Let us also invoke the constraint Strong $\Rightarrow$ STRESSED, which says that stressed syllables should align with $S$ positions (e.g., Rice 1996). This constraint is violated once by the first line (be), three times by the second line ( $m e, i t$, that and the last syllable of surfeiting) and twice by the third line (by the last syllable of appetite and and). On this analysis, the second line is metrically more complex because it has four violations of these constraints, whereas the other lines are less complex due to having only $1-2$ violations. The analysis also implies that line 3 is slightly more complex than line 1, which has one more constraint violation of STRONG $\Rightarrow$ STRESSED. This must be correct: generally, if the violations incurred by $A$ are a superset of those incurred by $B, A$ can hardly be less complex than $B$. In Optimality-theoretic literature, this is known as Harmonic bounding (Prince and Smolensky 2004, p. 210).

Furthermore, violating Weak $\Rightarrow$ UnStressed is presumably worse than violating Strong $\Rightarrow$ STRESSED, because, say, aligning a stressed syllable with a weak beat is rhythmically more disruptive than a beat that is simply "skipped" by an unstressed syllable. Under these assumptions, the constraint violations can be represented using an Optimality-theoretic tableau, where the constraints are listed left to right in the order of importance (Tableau 3.1).

| iambic pentameter | WEAK $\Rightarrow$ UNSTRESSED | STRONG $\Rightarrow$ STRESSED |
| :---: | :---: | :---: |
| (a) $-/-/-/-/-/$ |  | $*$ |
| (b) $/--/---/--$ | $*$ | $* * *$ |
| (c) $-/---/--/$ |  | $* *$ |

Tableau 3.1: Violations of WEAK $\Rightarrow$ UnStressed and STrong $\Rightarrow$ STRESSED in Twelfth night ll. 1-3
The asterisks $\left(^{*}\right)$ in each row under the constraint columns represent a constraint violation. Thus, in terms of the constraint violations, it can be seen that line (a) is the least complex of the three, followed by (c) and (b). This, of course, corresponds to the descriptive analysis given above.

The traditional OT framework (Prince and Smolensky 2004; McCarthy and Prince 1995), however, is not well suited for the study of meter. First, OT was designed to describe the way in which one form out of competing forms emerges as the winner from the interaction of lexicographically-ordered (i.e., strictly dominated) constraints. Metricality, as we have seen, is GRADIENT (Youmans 1989), in the sense that many phonological patterns can be used to instantiate a meter-in Optimality-theoretic terms, there are "multiple winners". Second, an essential idea of basic OT is that the competing forms (or CANDIDATES) are related to an input (i.e., an underlying form; e.g., Hyman 2018), from which they can deviate in various ways. In the study of meter, as Hayes and Schuh (2019, p. e261) point out, it makes more sense to concentrate on the well-formedness of different verse patterns than to derive them from a (possibly arbitrary) underlying form; this is also the approach of Hayes and Moore-Cantwell (2011) and Hayes et al. (2012). ${ }^{5}$

[^22]
### 3.2.2 Harmonic Grammars

To cope with gradience, the strict ranking of constraints in Classical OT can be replaced by constraint weighting, as in OT's predecessor, Harmonic Grammar (HG) (Smolensky 1986; Legendre et al. 1990; Smolensky and Legendre 2006). Before going on to see how weighted constraints can help to distinguish grades of well-formedness, it is useful to consider some of the basic principles of categorical HG. Like OT, HG operates with a set of interacting constraints that chooses a winner from a candidate set; but in HG the constraints are given numerical weights that represent their relative importance in the grammar. Each candidate is assigned with a harmony score, which is calculated as the dot product of the violation count vector and the constraint weights. Consider the following hypothetical example (the weights are made up for illustration): ${ }^{6}$

| weights: | Constraint 1 <br> 3 | Constraint 2 <br> 2 | harmony |
| ---: | :---: | :---: | :---: |
| Candidate 1 | -1 |  | $3 * 1+2 * 0=-3$ |
| Candidate 2 | -1 | -1 | $3 *-2+2 *-1=-5$ |
| Candidate 3 |  | -1 | $3 * 0+2 *-1=-2$ |
| Candidate 4 |  | -2 | $3 * 0+2 *-2=-4$ |

Tableau 3.2: Assigning harmony scores in HG

The winner is the one with highest harmony, in this case Candidate 3. An important feature of harmonic grammars is that they allow for cumulative constraint interactions, also known as GANG EFFECTS (e.g., Pater 2009). Consider this example:

| weights: | Con. 1 <br> 1.5 | Con. 2 <br> 1 | Con. 3 <br> 1 | harmony |
| ---: | :---: | :---: | :---: | :---: |
| Candidate 1 | -1 |  |  | -1.5 |
| Candidate 2 |  | -1 | -1 | -2 |

Tableau 3.3: HG gang effects: multiple constraints

[^23]In this case, the violations of the constraints 2 and 3 gang up on the stronger constraint 3, making Candidate 1 the winner. Similarly, multiple violations of a single constraint with a low weight can make another candidate optimal (this is sometimes called counting cumulativity):

|  | weights: | Con. 1 <br> 1.5 | Con. 2 <br> 1 |
| :---: | :---: | :---: | :---: |
| harmony |  |  |  |
| Can. 1 | -1 |  | -1.5 |
| Can. 2 |  | -2 | -2 |

Tableau 3.4: HG gang effects: single constraint
Gang effects do not occur in classic OT, since evaluation by ranking eliminates the candidates with more violations of a higher-ranked constraint. In HG, however, ganging happens automatically (being avoidable only with exponential differences between the constraint weights; see Prince and Smolensky 2004, p. 236), and is often considered as positive evidence for HG over OT (e.g., Jesney and Tessier 2008; Irvine and Dredze 2017; Zuraw and Hayes 2017; Breiss and Hayes 2019).

As we have seen, standard OT and HG are categorical, that is, the are designed to choose a single winner. The crucial step in accounting for gradience is to allow the grammar to produce variation by making it probabilistic. This is the problem that Maxent grammars address (e.g., Johnson 2002; Goldwater and Johnson 2003; Jäger and Rosenbach 2006; Hayes and Wilson 2008; Zuraw and Hayes 2017). It is important to emphasize again that metrical grammars are here envisaged as inputless (§3.2.1): we are not deriving anything but simply assessing the gradient well-formedness of different patterns. In statistical terms, the difference is between "conditional" and "unconditional" Maxent, or equivalently, between multinomial logistic regression (e.g., Jurafsky and Martin 2020, Ch. 5) and density estimation (Mohri et al. 2018, Ch. 12). The following review describes Maxent modeling from the perspective of density estimation, which is the method used here.

### 3.3 Maxent density estimation

Maxent grammars carry over from HG the idea of constraint weighting and the formula for computing harmony scores; but instead of choosing a single winner, they output a probability distribution over a set of forms. The basic idea is to build a grammar that

MAXIMIZES THE LIKELIHOOD (i.e., probability) of the data (e.g., Myung 2003). In other words, the goal is to model a dataset using such FEATURES (the statistical equivalent of constraints in OT and HG) that, when assigned suitable weights, can estimate a probability distribution that is close to the empirical distribution of the data. In order to make this work, we must first view the data as a random sample from an unknown probability distribution $(p)$, and assign an empirical probability $k / n$ to each data point $x$, where $k$ is the frequency of $x$ and $n$ the size of the sample. This yields an empirical probability distribution $(\hat{p})$. Since probabilities sum to 1 , maximizing the probability of the data will also minimize the probability of what is not observed, a rational goal (Hayes et al. 2012, p. 695).

A key principle behind Maxent is that though the empirical probability distribution of our sample $(X)$ may be different from $p$, it can be expected that the empirical averages of the features' values $(\hat{p}[f])^{7}$ are close to their true averages (e.g., Berger et al. 1996). The idea is then to seek a probability distribution $\tilde{p}$ that approximates the mean violation counts in the data for all features $(\tilde{p}[f]=\hat{p}[f])$; the problem is that there are typically many distributions satisfying this condition. By the principle of maximum entropy (hence Maxent), we should select the distribution that is maximally agnostic (Jaynes 1957), that is, the one that uses only $\hat{p}[f]$ as evidence, and nothing else (for motivation, see, e.g., Kesavan 2009). As Della Pietra et al. (1997) have shown, the probability distribution $\tilde{p}$ of maximum entropy that also satisfies $\tilde{p}[f]=\hat{p}[f]$ can equivalently be characterized as a Boltzmann-Gibbs distribution (Boltzmann 1868; Gibbs 1902), where the probability of each point $(x)$ in the sample is
(4) $\quad q_{\lambda}(x)=\frac{e^{\lambda \cdot f(x)}}{Z_{\lambda}}$
where $\lambda$ is the vector of feature weights, $\lambda \cdot f(x)$ is the dot product of the weight and feature value vectors, and $Z$ is a normalizing constant that sums the values of $e^{\lambda \cdot f(x)}$ for all $x$, ensuring that the distribution sums to 1 . Finding the $q_{\lambda}$ that maximizes the likelihood of the data (and, equivalently, the Maxent $\hat{p}$ ) is then a matter of computing the parameters $\lambda$. Because $Z$ varies as a function of $\lambda$, estimating $\lambda$ is typically only possible using numerical optimization techniques (Chong and Żak 2013), which makes

[^24]solving for $q_{\lambda}(x)$ a machine learning problem. ${ }^{8}$ In the machine learning literature, the formula in (4) corresponds to a version of the so-called SOftMax function (Bridle 1990).

As can be seen, the exponent of $e(\approx 2.71828)$ in the above formula corresponds to how the harmony scores are computed in HG (i.e., the dot product of weights and evidence; see §3.2.2 above). This is the link between HG and Maxent: the harmony scores are plugged to the softmax function, thereby making the candidates' probabilities proportional to the exponential of their harmony (Pater 2016, p. 26). As a probabilistic extension of constraint-based linguistics and metrics, Maxent has the key benefits of being a) transparent, in the sense that explanatory power of each individual constraint is easy to assess; b) convenient with diverse features that can be selected and augmented by the user (Mohri et al. 2018, p. 312); c) mathematically proven to have a unique solution (e.g., Della Pietra et al. 1997); and d) optimizable by any standard learning algorithm. ${ }^{9}$

### 3.3.1 Sample space

A fundamental principle of Maxent modeling is that a probability mass of 1 is distributed so that the predicted probability of observed data is maximized against unobserved forms. This implies that the sample space $S$ (i.e., the set of possible forms) should include not only attested forms but also many unattested ones-but how many? In the present case, the forms under consideration are strings of H and L syllables, and of course there are, in principle, infinitely many such strings. It turns out, however, that a small $S$ that excludes wildly unmetrical lines (say, lines with fifty Ls) is a "safe" replacement for an infinitely large set (Daland 2015; see also Hayes and Schuh 2019, p. e261 for discussion). In this dissertation, I define and delimit $S$ as that made up of all the combinations of the possible ways in which metrical positions (see §1.2) can be realized in the meter under scrutiny. For example, if we schematize the Greek iambic

${ }^{8}$ In this dissertation, I used a technique called gradient descent (e.g., Ruder 2016). The Maxent modeling scripts used in this dissertation are developed by me and are available from https://github.com/ezhenrik/. To make sure my algorithms are correct, I have verified that they give very similar results to those output by the widely used Maxent Grammar Tool (Wilson and George 2009)
${ }^{9}$ See also Hayes (2018, forthcoming) for why Maxent modeling makes sense intuitively.
sible patterns comes out to be 322 . The variant forms of the MPs themselves will in Chapter 4 be accounted for with constraints (see §3.4) that I assume to be inviolable.

### 3.3.2 Regularization

If a constraint is violated by some of the included candidates but never in the observed data, the condition that $\tilde{p}[f]=\hat{p}[f]$ makes that constraint approach $\infty$ (e.g., Johnson 2013). This is not just computationally inconvenient; it is also generally wrong to infer from the observed to the unobserved. In general, the empirical averages of features are almost never equal to their true expectations (Dudík et al. 2007), so conditioning the model on their equality can lead to overfitting (i.e., the model does not generalize well to unseen data). This is addressed by REGULARIZATION, which discourages the model from learning large weights. In this dissertation, I used the Gaussian Prior method (Chen and Rosenfeld 2000), where the evidence is balanced against a prior expectation that each feature has a mean $\mu$ and a variance $\sigma^{2}$. We then find the model that maximizes the posterior probability of the model that satisfies

$$
\begin{equation*}
\tilde{p}\left[f_{i}\right]=\hat{p}\left[f_{i}\right]-\frac{\left(\lambda_{i}-\mu_{i}\right)}{\sigma_{i}^{2}} \tag{5}
\end{equation*}
$$

for each feature $\left(f_{i}\right)$ in the model. That is, the empirical expectations $\hat{p}(f)$ are "discounted" by the $\frac{\left(\lambda_{i}-\mu_{i}\right)}{\sigma_{i}^{2}}$. In this dissertation, I used $\mu_{i}=0$ for each feature and $\sigma_{i}^{2}=1$ (as recommended by Klein and Manning 2003), which has the effect of smoothing the model towards uniformity (Chen and Rosenfeld 1999, p. 10), countering the issues pointed out above.

### 3.3.3 Estimating model performance

Although the maximum likelihood method is mathematically proven to find the optimal feature weights, it says nothing about the validity of the model itself. Estimating models can be divided into two sub-tasks: 1) SELECTING the best model from a set of candidate models and 2) Evaluating the predictive power of the best approximating model (Raschka 2018). Let us consider both in turn.

### 3.3.3.1 Model selection

A basic principle of model selection is that when two models have similar predictive power, the better (or more PARSIMONIOUS) model is likely the simpler one (Box and

Jenkins 1970, p. 17). Adding features to a model generally increases its fit to the analyzed data but reduces its generality; the goal is to achieve a proper tradeoff between the two. The present work uses a BACKWARD sequential model selection procedure: I start with a constraint set that achieves a good fit, and then remove constraints one at a time to see if the smaller model would fare just as well. Several strategies exist to choosing the best model from among candidates (e.g., Lewis et al. 2011); I used a second-order variant of the Akaike Information Criterion (AIC) (Akaike 1973; Sugiura 1978):

$$
\begin{equation*}
A I C_{c}=-2 \ln (\hat{L})+2 K\left(\frac{n}{n-K-1}\right) \tag{6}
\end{equation*}
$$

where $n$ is the number of observations, $K$ is the number of estimated parameters and $\hat{L}$ the maximum likelihood of the data given the fitted model (see §3.3) above. In short, the formula penalizes model complexity against accuracy, with adjustments for sample size (see Burnham and Anderson 2002, Section 2.2 for the details). In itself, the $\mathrm{AIC}_{\mathrm{c}}$ values mean nothing; what matters is the difference between models
(7) $\Delta_{i}=A I C_{c_{i}}-A I C_{c_{m i n}}$
where $A I C_{c_{\text {min }}}$ is the model with the lowest (i.e., "best") $\mathrm{AIC}_{\mathrm{c}}$ value and $A I C_{c_{i}}$ some other model. $\Delta_{i}$ indicates the information loss when using the model $q_{i}$ instead of $q_{m}$ in for inference (AIC and $\mathrm{AIC}_{\mathrm{c}}$ are closely related to the information-theoretic KullbackLeibler Divergence; e.g., Akaike 1983).

In interpreting $\Delta_{i}$ values it is common to rely on the rule of thumb given by Burnham and Anderson (2004, p. 271): "Models having $\Delta_{i} \leq 2$ have substantial support (evidence), those in which $4 \leq \Delta_{i} \leq 7$ have considerably less support, and models having $\Delta_{i}>10$ have essentially no support". $\Delta_{i}$ values can also be used to calculate the EVIDENCE RATIO of two models by comparing the likelihood of the models given the data (Akaike 1981; Burnham and Anderson 2004, pp. 271-2):
(8) $e\left(-\Delta_{i} / 2\right)$

In the Maxent models of Greek meters described in Chapter 4, I give both measures.
Although $\mathrm{AIC}_{\mathrm{c}}$ can be used to select the best model among candidate models, it cannot tell if all of them are poor. Since this dissertation compares only a very limited
set of different models without justifying the exlusion of others (see Chapter 4), the analyses should be understood as more exploratory than confirmatory in nature (Burnham and Anderson 2002, p. 47). ${ }^{10}$ However, there are ways to assess the performance of the $\mathrm{AIC}_{\mathrm{c}}$-best model, which I turn to next.

### 3.3.3.2 Model evaluation

To assess the goodness of fit of the models (i.e., how closely the predicted frequencies mirror the observed ones), I used the $R^{2}$ metric, adjusted for the number of features included (notated $R_{a d j}^{2}$; for explanation and the formula, see, e.g., Miles 2014). In general, the closer $R_{a d j}^{2}$ gets to 1 the better the model is fit to the data; however, in itself the value can easily be misleading (e.g., Shalizi 2015) and should only be used in combination with data visualizations and other statistics (Frost 2019, p. 132). To visualize the results, I use scattergrams, with $x$-axis showing the predicted and $y$-axis the observed frequencies, and data points indicated using dots (see, e.g., Figure 4.4 in Chapter 4). Examining the fit visually is straightforward: the closer the points are to a diagonal regressed line, the better the predicted values match the observed ones.

We also want to test the models' skill to predict unseen data. I used a method called $k$-fold cross-validation (e.g., Guyon et al. 2010) for this purpose. The dataset is first split into $k$ consecutive batches or "folds". The model is then fitted $k$ times, each time using $k-1$ folds as training data, and the remaining fold as testing data. A five-fold cross-validation is illustrated in Figure 3.5.

In each iteration, we fit the model using the $k-1$ training folds and evaluate the fitted weights on the test set, and retain the obtained weights and $R_{a d j}^{2}$ scores. After $k$ runs, the cross-validation performance is summarized by averaging the weights and $R_{a d j}^{2}$ scores.

[^25]

Figure 3.5: Five-fold cross-validation

### 3.3.4 Incorporating a prose baseline using Gaussian priors

At the heart of Maxent modeling is Laplace's principle of insufficient reason (Laplace 1812), which says that if in an experiment there are $n$ possible outcomes and no additional information is available about the process, the most reasonable guess is that each outcome is equally likely $(1 / n)$. To update that prior belief, Maxent uses the features' expected values, as explained above. Laplace's principle, however, is only valid when one is truly ignorant about a system, which is not the case here: the lexical statistics of Greek makes the candidate lines for a given meter a priori unequiprobable (e.g., Devine and Stephens 1976). Assessing whether the observed frequencies are the result of intentional metrical composition or merely reflexes of linguistic factors is commonly known as the "Russian method" (e.g., Tarlinskaja and Teterina 1974; Tarlinskaja 1976; Bailey 1979; Gasparov and Tarlinskaja 1987; Biggs 1996; Hayes and Moore-Cantwell 2011; Ryan 2011b; Hayes 2013). This section describes a novel implementation of the Russian method using Maxent.

### 3.3.4.1 Generating random verse

I first collected a corpus of prose data ${ }^{11}$ and used it as training data to build an N-GRAM Language model (LM) (Jurafsky and Martin 2020, Ch. 3). LMs are based on the Markov assumption that the occurrence of a word is conditional to the probability of $n-1$ words preceding it. A LM can be used to generate text by 1) choosing a random word in the corpus; 2) selecting a high-probability context for that word; 3) repeating

[^26]step 2 for the new last word; and 4) continuing until some predefined limit is reached. My algorithm uses bigrams (i.e., a context of length 1), which produces adequately real-looking (though far from fluent) Greek. ${ }^{12}$

In order to produce verse, the LM-generated random sentences need to be annotated for syllable weight, so it can be seen whether an accidental verse has turned up in some meter. In the present case, manual annotation was not feasible due to the large size of the prose corpus. Instead, I used the script developed by Conser (2017), which uses various heuristics to scan Greek texts; but since syllable weight is often ambiguous in Greek orthography (e.g., $\iota, \alpha$ and $v$ can be either long or short), the script cannot scan all syllables. In examining a sample of the syllables that Conser's script could not parse, I found that around $9 / 10$ were $L$; this coincides with the fact that ambiguous syllables are in Greek generally more often L than H (Mastronarde 2013, p. 39). Using that as a rough approximation, I modified Conser's algorithm so it randomly scans ambiguous syllables as L or H with a $90 \%$ probability of assigning L .

Finally, based on the idea that the absolute limits of metricality can be defined in terms of the different combinations of metrical positions (see §3.3.1 above), I collected corpora of nonsense verse by retaining those random sequences that fit within the limits so defined.

### 3.3.4.2 A Maxent implementation

Suppose we have constructed a constraint-based metrical grammar and fitted it to an empirical dataset of verse; now we want to see if the constraints reflect true metrical preferences instead of just lexical statistics. My proposed Maxent-based method implements Gaussian priors to test for the latter possibility as follows. First, the chosen grammar is fit to the random corpus and the obtained weights are retained. Then, going back to the real corpus, a model is fit on it $K$ times $(K=$ the number of constraints in the grammar), and in each iteration, the $\mu$ of the $K$ th constraint's Gaussian prior is set to the weight obtained for the same constraint in the fitted random model. In addition, the $\sigma^{2}$ of the constraint is set to 0.001 , which forces its weight to stay close to $\mu$; we do not want the real data to wipe out the baseline effect. Finally, the $K$

[^27]models with the baseline-priors are compared to the full model using $\mathrm{AIC}_{\mathrm{c}}$ (see §3.3.3.1 above). ${ }^{13}$

### 3.4 Constraints

This section introduces and discusses the metrical constraints that will be used in the Maxent models of selected Greek meters in Chapter 4. ${ }^{14}$ The following constraints are meant as formalizations of poets' metrical intuitions, expressing the preferred (but flexible) mappings between metrical grids (on which see Chapter 2) and the rhythmic patterns of verses. To avoid confusion, it may be useful to repeat (from §2.1.2) that the grid- and constraint-based analysis proposed here is not meant as a conjecture about the timing of Greek verse in performance; rather, it is an effort to make sense of the recurring prosodic patterns that are found in verses (see Hayes and Schuh 2019, pp. e279-e284 for a similar approach).

### 3.4.1 Durational matching

A basic property of Lerdahl-Jackendovian (1983) grids is that for every "attack point" in a sequence there must be a gridmark to which it can be mapped. In poetic meter, the attack point can be conceptualized as the left margin of a syllable. ${ }^{15}$ The shortest

[^28]interval between syllables in mora-based quantitative meter is that between two $\mathrm{Ls},{ }^{16}$ which means that the gridmarks at the lowest metrical level correspond with moras. A natural alignment between moras $(\mu)$ and grids is as follows:
(9) Durational matching
\[

$$
\begin{gathered}
\mathrm{x} \\
\mid \\
\mu
\end{gathered}
$$
\]

The role of the DURATIONAL mATChing constraints, then, is to express the poets' assumed preference to generally match the mora "slots" in the grid with moras in the phonological representation of the verses. The following constraints will describe this preference in negative terms, as various durational misalignments that poets presumably want to avoid. ${ }^{17}$ First, ${ }^{*}$ Empty will penalize the situation where a mora slot is not mapped to anything:
(10) Violation of *Empty ("No empty grid positions")

```
x
|
```

In poetic meter, ${ }^{*}$ Empty is violated by truncation (i.e., catalexis and headlessness; see §1.3.6). Its opposite are moras that are unassociated with any grid position, often termed extrametrical (e.g., Liberman and Prince 1977, p. 273). To penalize extrametrical moras, I formulate the constraint $*$ FloAt:
(11) Violation of *FloAt ("No extrametrical moras")

```
        \varnothing
```

[^29]As pointed out above, on the Lerdahl-Jackendovian analysis every attack point (i.e., syllable) must be mappable to the grid, which implies that *Float is in fact inviolable. I will assume that this is the case in Greek poetry.

Thus, *Empty and *Float enforce a basic one-to-one mapping between moras and positions in the grid. Accordingly, H syllables map most naturally to the grid as follows:
(12) Durational matching between H and grid

## x x

$1 /$

Even if a mapping respects both *Empty and *Float, there are other ways for it to defy durational matching. For instance, a single mora could be associated with more than one grid position. This can be called a *Stretch violation:
(13) Violation of *Stretch ("No sharing of moras with two or more grid positions")


In the Greek meters that I analyze in this dissertation, *Stretch appears to be inviolable. This is not true, however, of Greek versification generally: there are verse forms in which the external responsion between H and HL does seem to require stretching the H by the length of one mora to match durationally with HL (West 1982a, p. 22).

The opposite of stretching is a mapping where a single gridmark is shared by more than one mora. Greek, as I will show in the next chapter, appears to treat such mappings differently depending on whether the moras belong to the same $(\mathrm{H})$ syllable, or to two or more syllables. The former case can be expressed as a *SQueeze violation:
(14) Violation of *Squeeze ("No sharing of gridmarks by two or more moras") x
I
H

According to West (1992, p. 132), there are no examples of "a long syllable being shortened" in Greek poetry. As I try to demonstrate in the next chapter, squeezing is
in fact common in the so-called anceps positions $(\times)$, to which $\mathrm{L}, \mathrm{H}$ and exceptionally also LL can be mapped. On my analysis, anceps - a hallmark of iambic rhythm (...× $-\cup-\times \neg-\ldots)$-is most straightfowardly analyzed as a single gridmark column, to which H syllables must be squeezed to fit.

The second case, i.e., the mapping of more than one syllable $(\sigma)$ to a single grid position violates a constraint I will call * Crown:
(15) Violation of *CROWD ("No sharing of gridmarks by two or more syllables")


The minimal violation of $*$ Crowd is when the sequence $L L$ is mapped to a single mora slot. In Greek, is also appears to be the only kind.

Together, these basic preferences, expressed in terms of *Empty, *Float, *Stretch, ${ }^{*}$ Squeeze and ${ }^{*}$ Crowd, suffice to describe the basic durational limits and varieties of the meters analyzed in Chapter 4.

### 3.4.2 Prominence

Prominence alignment constraints relate the prominence levels of the grid to syllabic prominence levels, and vice versa. As explained in the previous chapter (§2.2.4.2), H syllables are generally perceived as more prominent than L syllables, and therefore map naturally to strong gridmark columns. Note that it must be the first moras of Hs that are mapped to strong positions; a H syllable that ends in a S is off-beat and perceived as syncopated (to which I return shortly). The relevant constraint will be called $\mathrm{STRONG} \Rightarrow$ LONG: ${ }^{18}$
(16) Violation of Strong $\Rightarrow$ Long ("Strong positions are initiated with H")

```
x
x x
| /
*H
```

[^30]Because prominence is hierarchical, we may also invoke constraints that relate to higher levels in the grid. In stress-based meters, stronger prominence in the grid can mean an increased probability to either match the position with a stressed syllable (e.g., Tarlinskaja 1976) or an attraction to some higher-level stress in the prosodic hierarchy (Hayes 1989b). In quantitative meters, metrical strength corresponds positively to the attraction of heavy syllables (Prince 1989; Hanson and Kiparsky 1996; Dell and Elmedlaoui 2008; Schuh 2011; Hayes and Schuh 2019).

In addition to strong positions (i.e., columns with two levels of gridmarks), I will be referring to "superstrong" and "hyperstrong" positions (three and four levels, respectively). The corresponding constraints are Superstrong $\Rightarrow$ Long and Hyperstrong $\Rightarrow$ Long, and their definitions should be clear. It is important to emphasize that the constraints in the $[$ Strengith $\Rightarrow$ Long family are here assumed to be in a subset or Stringency relationship (e.g., De Lacy 2002). Namely, a violation of a higher-level prominence constraint will also imply a violation on the lower levels (i.e., violating Hyperstrong $\Rightarrow$ Long implies violations of both Superstrong $\Rightarrow$ Long and $\operatorname{Strong} \Rightarrow$ Long $)$. This makes it possible to examine possible cumulative effects of metrical strength (see, e.g., Hayes et al. 2012, p. 704).

The opposite of $\operatorname{Strong} \Rightarrow$ Long family constraints are constraints that express the avoidance to initiate a H in a weak gridmark. The basic constraint of this type is LONG $\Rightarrow$ STRONG:
(17) Violation of LONG $\Rightarrow$ STRONG ("No H onsets in weak positions")


Like $\operatorname{Strong} \Rightarrow$ Long, Long $\Rightarrow$ Strong could be conceptually extended to higher levels of the hierarchy (Long $\Rightarrow$ Superstrong, etc.), but it is not evident that such constraints are relevant in Greek poetry.

When a H is initiated in a weak position and not squeezed, the result is SyncopaTION. In ternary grids, LONG $\Rightarrow$ STRONG is violated regardless of whether the final mora of H is aligned to a S position. That is, the constraint cannot differentiate between these two syncopated patterns:

$$
\begin{align*}
& \begin{array}{llllllllll} 
& \mathrm{x} & & & & & & \\
\mathrm{x} & & & & \\
\mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \ldots & \ldots \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \ldots
\end{array}  \tag{18}\\
& \text { H L L L L H }
\end{align*}
$$

This will be addressed in Chapter 5, where I discuss syncopation in Greek meter in some detail.

### 3.4.3 Final strictness

As discussed in $\S 1.3 .3$, throughout metrical traditions there is a tendency for metrical constituents (metra, cola, lines, etc.) to increase in rhythmic regularity towards the end. On the present analysis, this means a stricter obedience of constraints such as Strong $\Rightarrow$ LONG or ${ }^{*}$ SQUEEZE. Although strictness effects are most closely associated with lines, they have been shown to affect sub-patterns as well (e.g., Hayes et al. 2012). In the present study, I will only use line-level strictness constraints (with one exception to be discussed in §4.1).

### 3.4.4 Syllable sequences

The constraints formulated thus far evaluate the mappings of individual syllables in isolation. But as Jespersen (1933) was the first to suggest, a plausible constraint family would evaluate sequences of syllables (see also Hayes et al. 2012, p. 701). In Greek meters, there appear to be two relevant types of constraints targeting consecutive syllables.

The first type penalizes unmodulated sequences. In particular, consecutive stretches of L syllables are avoided, a phenomenon which is also attested in Arabic (Schuh 2011) and Chadic meters (Schuh 2014; Hayes and Schuh 2019). As Schuh (2014) points out, such sequences are probably avoided for rhythmic reasons, in order to maintain a palpable rhythmic flow. In principle, both long stretches of L and H syllables can cause rhythmic disruption. I will simply call the relevant constraints *LLL and *HHH. Sequences of more than two L or H syllables, respectively, will incur a violation, regardless of the underlying grid structure they are mapped to.

The second type is related to the relative prominence of consecutive syllables and their mapping to consecutive positions in the grid. In their Maxent models of English iambic pentameters, Hayes et al. (2012, p. 701) used such constraints to penalize equal stresses in S-W and W-S sequences: FALL FROM STRONG penalizes a configuration where the level of stress is equal or higher in a weak position following a strong one;
and Rise to strong penalizes an equal or stronger stress in a W compared to the S that follows it. ${ }^{19}$ A quantitative extension of such constraints is plausible: because H is more prominent than L , we can use Fall from strong such that it is violated by any mapping to $\mathrm{S}-\mathrm{W}$ other than $\mathrm{H}-\mathrm{L}$; and accordingly, Rise to strong would assess a violation for all $\mathrm{W}-\mathrm{S}$ mappings except $\mathrm{L}-\mathrm{H}$. It is also plausible that the higher levels of prominence in the metrical hierarchy are especially prone to attracting rising or falling rhythms, expressible in terms of constraints such as Rise to superstrong ("W-SS must be aligned with L-H") or Rise to hyperstrong. Indeed, the Greek anapestic meters can be analyzed as observing Rise to hyperstrong, as I show in the next chapter.

### 3.5 Summing up

Maxent models are based on the principle that the best estimate of an unknown probability distribution is the one that is maximally uniform, subject to the expectation that the average value of each feature is close to its empirical average. In its metrical incarnation, Maxent models have been used as probabilistic "metrical grammars" that seek to frequency-match the observed line types in metrical corpora. There are many good reasons to use Maxent in metrical analysis: it uses and extends the widely adopted Halle-Keyserian frequency hypothesis, is backed with mathematical proofs, and allows for easy access to the models' internals - a particularly important point, since the main goal of metrics is to discover the basic principles of metrical composition and their relative importance, something the constraint weights show transparently. This chapter reviewed some of the basic mechanisms of Maxent modeling and model comparison. In addition, it introduced a novel way to assess the effects of statistical patterning of language in versification, using Maxent. The proposed method models the baseline effect of lexical statistics using Gaussian priors, whose values are found by fitting a metrical grammar to a body of artificial verse, generated using n-gram language models. With such baseline-priors, the necessity of each constraint can be appraised by seeing how much its weight budges from its prior in the real dataset.

[^31]The second part of the chapter formulated four categories of violable constraints for the analysis of quantitative verse: 1) Durational matching constraints express the basic one-to-one mapping between moras and grid columns; 2) Prominence mapping constraints describe the natural propensity of heavy syllables to align with metrically prominent positions; 3) Final strictness constraints are used to model increased rhythmic regularity towards the ends of metrical constituents; and 4) Syllable sequence constraints penalize the lack of quantity modulation in strings of syllables.

## Chapter 4

## Maxent models of four Greek

## meters

Having looked at the basic anatomy of Greek meter (Chapter 1), the construction of metrical grids (Chapter 2) as well as a Maxent modeling method for the probabilistic analysis of meter using weighted constraints (Chapter 3), we can now turn to the empirical part. This chapter offers analyses of four Greek meters using Maxent: trochaic tetrameter catalectic, iambic trimeter, comic iambic trimeter, and anapestic dimeter. These meters were chosen because they are well represented in the surviving ancient Greek literature, allowing for principled statistical analyses. ${ }^{1}$ Each analysis proceeds the same way: I first give the traditional schema of the meter, a few example lines, followed by a brief discussion of the relevant metrical data. I then construct a metrical grid that hypothetically underlies the verses. The Maxent modeling begins with a definition and delimitation of the sample space in terms of inviolable pattern constraints (see $\S 3.3 .1$ ), and the choice of constraints that represent violable preferences. The grammar is then fitted to the data, cross-validated (§3.3.3.2), then augmented with priors obtained from a baseline model (§3.3.4), followed by a restrictiveness test. The final sections of each analysis offer notes on performance rhythm.

[^32]
### 4.1 Trochaic tetrameter catalectic

The basic quantitative schema of the trochaic tetrameter catalectic is as follows:


The meter has been traditionally understood to consist of four trochaic metra, whose basic form is $-\cup-\times$, with optional resolution in principia ( $\simeq \simeq)$, except for the last one which is always - (see $\S 1.3 .2$ ). On this analysis, the last metron is catalectic, that is, one position shorter than the first three metra ( $\left(\underline{\sim}-{ }_{\wedge}\right)$. There is an obligatory break between two words (caesura) after the second anceps, which divides the line into two distinct halves. Here are some example lines, taken from Aeschylus' Persians (173-175):
(2) ê̂ tód' isthi, gês ánassa têsde, mé se dìs phrásai H L H L H L H L| H L H L H L H
"Rest assured, queen of this land, you don't need to ask twice"
mét' épos mét' érgon ôn àn dúnamis ēgeîsthai thélēei:
H L H H H L H H| LL L HH H LH
"if we may council you by word or feat,"
eúmeneîs gàr óntas hēmâs tônde sumboúlous kaleîs
H L H H H L H H| H L H H H LH
"for we, whom you call, are disposed to advise you."

### 4.1.1 The data

The analyzed dataset includes 430 lines and consists of all intact surviving Archaic tetrameters attributed to Archilochus and Solon (63 lines), all lines from the tragedies of Aeschylus and Sophocles (167) as well as a random sample from Euripides (200). Figure 4.1 shows the percentages of H in princeps positions (versus the resolved LL) and L in breve and anceps positions in each foot ("foot" being the traditional constituent that divides a metron in two halves, in this case $\simeq \simeq \cup$ and $\underline{\backsim} \times$ ).

As the figure shows, resolution of principia is rare - on average only $2.94 \%$ of nonfinal principia are LL. Further, resolution is more frequent in odd $(0.83 \%)$ than in even $(4.42 \%)$ princeps positions. Ancipitia, on the other hand, are on average slightly


Figure 4.1: Syllable types in trochaic tetrameters
more often $\mathrm{H}(52.2 \%)$ than L , but the proportions vary widely: H is the more common option in the second anceps ( $69.8 \%$ ) but is avoided in the third one ( $37.0 \%$ ); in the first anceps the difference is negligible $(50.5 \% \mathrm{H}, 49.5 \% \mathrm{~L})$.

### 4.1.2 Metrical structure

Ancient theory classified the trochaic tetrameter in the IAMBIC family of meters (e.g., Aristotle, Rhetoric 1418b), which is based on the repeatable sequence $\ldots \times-\cup-\times$ $-\cup \ldots{ }^{2}$ The base unit of construction in this family is the iambic metron $\times-\cup-$, as the meters always start either in the sequence $\times-$ (called iambic meters) or $-\cup$ (trochaic meters) but never $\smile-$ or $-\times$ (West 1982a, p. 19). For these reasons, it makes some sense to interpret the trochaic variant as a headless version of the more basic iambic metron $\wedge_{\wedge}-\cup-$, which would make the trochaic tetrameter a headless iambic tetrameter: $\wedge-\smile-, \times-\smile-, \times-\smile-, \times-\smile-$ (Golston and Riad 2000; Kiparsky 2018). I return to this point shortly below.

There are two plausible ways to construct a grid based on the metron $\times-\cup-$, depending on what rhythmic value one assigns to the variable anceps position (see §3.4 for the basic verse-grid mapping constraints). On the interpretation that H is the more basic variant, one could induce the following grid:

[^33]```
X X X
X X X X X X X X X
```

This analysis is supported by the observation that H is, on average, slightly more frequent in anceps positions (§4.1.1). However, the asymmetrical rhythm $(2+3+2)$, though structurally well-formed (Lerdahl and Jackendoff 1983, p. 72) and ubiquitous in music (§2.2.2.1), is dubious in light of ancient rhythm theory ${ }^{3}$ as well as the fact that the last anceps of the line is much more often L than H , an evident final strictness effect (§1.3.3). The more plausible alternative therefore seems to be the following, simpler grid, where H in anceps needs to be "squeezed" to a single grid column (§3.4.1):

| X |  | X |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
| X | X | X | X | X |  |
| $\times$ | - |  |  |  |  |

A testable hypothesis is that the higher frequency of H is not in fact intentional but merely a reflex of the statistical patterning of words in ancient Greek. This indeed seems to be the case, as I will demonstrate shortly (§4.1.6) using Maxent models that incorporate a prose baseline.

Recall also from §4.1.1 that on average, odd princeps positions are more frequently resolved than even princeps positions. This can be tentatively analyzed as a metrical prominence effect: every other princeps is metrically stronger ("superstrong"; see §3.4.2) and so requires H syllables more strictly. On such an analysis, the augmented hierarchy looks as follows:

|  |  |  |  | X |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | X |  |  | X |  |
| X | X | X | X | X | X |
| $\times$ | - |  |  | - |  |

For now, let us simply assume that (5) is correct, and that the full pattern consists of four of such patterns in sequence - with one modification: to make the pattern trochaic, we move the line-initial gridmark to the end. Although trochaic tetrameter can, as pointed out above, be analyzed as a headless iambic tetrameter (see also §4.1.3.1

[^34]below), there are good reasons to believe that the synchronic structure of the meter is genuinely trochaic. This is strongly suggested by the invariable caesura after the second anceps, which effectively makes the meter a couplet of two trochaic dimeters, with a $8+7$ structure (Korzeniewski 1968, p. 64). On the iambic analysis with an initial instead of final empty position (as in Kiparsky 2018, p. 100), the division would instead be $7+8$. As was discussed in $\S 1.3 .6$, it is natural for meters to end periods (such as couplets) in shorter lines than those that precede it, but not the other way around. Final truncation is also attested elsewhere in Greek versification: for instance, anapestic periods normally end in a catalectic variant (Parker 1976; §4.4 below). It is also interesting to note that in the manuscript tradition, the two trochaic cola are sometimes written in separate lines (Gentili and Lomiento 2003, p. 264).

Based on the above assumptions and observations, the full structure of the trochaic tetrameter can be visualized as follows:

|  |  |  | X |  |  |  |  |  | X |  |  |  |  |  | X |  |  |  |  |  | X |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| X |  |  | X |  |  | X |  |  | X |  |  | X |  |  | X |  |  | X |  |  | X |  |  |
| X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |  |

The following sections formulate the constraints that will express the correspondences between verses and the metrical grid above. We will then use Maxent to see whether the proposed analysis can be used to accurately model the dataset's frequency distribution of different rhythmic patterns.

### 4.1.3 Constraints

As explained in §3.3.1, for computational tractability, we first need to delimit the space of logically possible patterns. In the present framework, such limits can be defined using inviolable constraints, which I will call Pattern CONSTRAINTS.

### 4.1.3.1 Pattern constraints

Before going on to formulate the constraints, let us reflect on why the basic pattern of the iambic metron is $\times-\cup-$ instead of, say, $\smile-\cup-, \cup-\times-$. A formal account is given by Prince (1989), who argues that the iambic metron embodies an abstract hierarchical rhythmic structure, representable as a labeled tree (Liberman 1975; Liberman and Prince 1977). According to this analysis, the iambic metron branches into two feet (W and $S$ ), both of which, in turn, branch into two metrical positions ( W and S ):


This hierarchical structure would explain why the anceps position is at the left edge of each metron: anceps corresponds to the weakest position in the tree, being the only one that is both itself W and belongs to a W branch. As I see it, the analysis has two shortcomings. First, as Kiparsky (2020, p. 2) points out, in a tree representation, the branches are formally equivalent to brackets in a grid representation, both of which represent metrical constituents, whose existence is motivated by regularities in phrasing (see $\S 2.2 .4 .3$ ). However, as has already been pointed out, the Greek iambic metron is evidently not a grouping structure at all: metra are straddled in almost every trochaic tetrameter line by the medial colon boundary; and the same straddling is common in iambic trimeter, as will be seen shortly below (§4.2). Second, and more seriously, Lerdahl and Jackendoff (1983, pp. 24-29) argue compellingly that metrical prominence is not a property of metrical groups, but strictly of metrical beats (= gridmarks). Prince's (1989) tree-based analysis, by contrast, interweaves metrical prominence and grouping, with the result that weak positions can differ as to their metrical prominence depending on the strength of the branch they belong to-an impossibility, if Lerdahl and Jackendoff are right. ${ }^{4}$

It is conceivable, however, that in pre-historical poetry the iambic metron was an authentic element of composition, whose edges poets tended to align with phrase boundaries. The phrase patterns of early Greek verse give some support for such a hypothesis (Kiparsky 2018, pp. 107-110), and additional evidence comes from the genealogically related Vedic Sanskrit iambic meters, where metron-matching is common (see, e.g., Gasparov 1996, p. 8, and Chapter 5 of this dissertation). It could then be

[^35]conjectured that even after the metron as a compositional unit was supplanted by the asymmetrical cola that have come down to us, the position of the anceps (originally at the left edge of the metron-group) would have been retained as a historical convention in the periodic metric pattern. In this diachronic view, the metron-initial anceps can be understood as an initial laxness effect (see §1.3.3).

Left-edge metrical laxity can be analyzed in terms of POSITIONAL LICENSING CONSTRAINTS, which appear sporadically in phonological analysis (Kager 2001, 2005; Kaplan 2018). ${ }^{5}$ I will use the negation symbol $(\neg)$ in the constraint's name to denote the position in the meter where the constraint in question makes an exception. In this case, the relevant pattern constraint will be called *SQUEEZE $\neg$ (L, Metron), or "No squeezing, except at the left edges of metra". Assuming that the constraint is inviolable, it formalizes the fact that squeezing is allowed at ancipitia but banned everywhere else in the line.

The other constraints that are inviolable in trochaic tetrameters are the durational mapping constraints *Stretch, *Float, ${ }^{*}$ Crowd, and the prominence mapping constraint LONG $\Rightarrow$ STRONG (no syncopation). Last, we must also account for the obligatory line-final empty position, or catalexis. One possibility would be to again appeal to diachrony and conjecture (with Golston and Riad 2000 and Kiparsky 2018) that in the ur-meter it was the line-initial position that was missing-perhaps another initial laxness effect, which could be expressed using a constraint such as ${ }^{*}$ Empty $\neg(\mathrm{L}$, Line) ("No empty positions, except at the beginnings of lines"). But I propose a different analysis, based on the idea that the meter is a $8+7$ couplet (see $\S 4.1 .2$ above): the linefinal violation of *Empty serves to make the couplet salient, in the sense of Hayes and MacEachern (1998, p. 485) and Kiparsky (2006a, p. 17) (see also §1.3.6 for discussion). In short, Saliency requires that the couplet's last line is more "cadential" (namely, shorter) than the first one, instead of being of equal $(8+8)$ or longer (e.g., $7+8$ ) length.

The pattern constraints that define the allowable variation in the tetrameters are listed in Table 4.2, for convenience. Under these constraints, we get a sample space of 1024 different quantitative patterns based on the grid shown in (6). In my dataset, only 39 of them are attested. Note that the constraints still allow for clearly unmetrical patterns to emerge, such as LL L LL L LL L LL L LL L LL L LL L H. Although

[^36]| Constraint | Definition |
| :--- | :--- |
| ${ }^{* S Q U E E Z E} \neg($ L, Metron $)$ | No squeezing except at left edges of metra |
| ${ }^{*}$ Stretch | Moras are mapped to no more than one gridmark column |
| ${ }^{*}$ Float | No extrametrical moras |
| ${ }^{*}$ Crowd | No sharing of gridmarks by two or more syllables |
| LONG $\Rightarrow$ STRONG | Long (i.e., non-squeezed) Hs are initiated in S positions |
| Saliency | Couplets have a $7+8$ structure |

Table 4.2: Pattern constraints for trochaic tetrameters
it would be possible to exclude such lines from consideration using some additional pattern constraint (say, *LLLL), the preference constraints, which are formulated in the next section, turn out to do the job just fine.

### 4.1.3.2 Preference constraints

Turning to the violable preference constraints, first, the preference to fill principia with H syllables (see §4.1.1 above) can be formally implemented with Strong $\Rightarrow$ Long. It was also noted above that odd strong positions are generally less resistant to resolution than even positions. Based on the proposed grid structure shown in (6), this can be formalized with the constraint Superstrong $\Rightarrow$ Long, which expresses the idea that superstrong positions require Hs more rigidly than strong positions. Figure 4.1 also shows that resolution is very rare in the line-final metron. ${ }^{6}$ This looks like a final strictness effect (§1.3.3), which I will analyze using Strong $\Rightarrow$ Long(Clausula), where the "clausula" is indexed to the last iambic metron (i.e., targeting the three last strong gridmarks).

Next, we deal with the various manifestations of the three ancipitia. Recall first that almost two-thirds of line-final ancipitia are L-another effect apparently stemming from final strictness. I will formalize this with the constraint *SQueeze(Clausula), which penalizes squeezing in the clausula, as defined above. As for the second anceps, from the perspective of the present analysis it is "unnaturally" filled with H more often than

[^37]| Constraint | Weight | AIC $_{\mathrm{c}} \Delta$ | Evidence ratio |
| :--- | ---: | ---: | ---: |
| Strong $\Rightarrow$ LonG | 2.84 | 1246.70 | $>10000$ |
| Superstrong $\Rightarrow$ Long | 1.53 | 34.42 | $>10000$ |
| Strong $\Rightarrow$ Long(Clausula) | 1.09 | 12.60 | 545.24 |
| *SQuEEZE(Clausula) | 0.53 | 27.46 | $>10000$ |
| *SQuEEZE(R, Colon) | -0.83 | 67.03 | $>10000$ |

Table 4.3: Constraint weights for trochaic tetrameters: simple model

L, indicating, as it seems, that squeezing is actually preferred here (but as my analysis will shortly demonstrate, this "preference" may be illusory). Let us simply express this observation, without trying to explain it, using the constraint *Squeeze( R , Colon) "No squeezing at the right edges of cola". Since squeezing in the second anceps is actually the more common option, it is to be expected that the constraint obtains a negative weight, meaning that the model rewards lines for colon-final squeezing (in other words, violating *SQuEEzE(R, Colon) will make lines more probable). Last, the first anceps requires no additional constraint, since here L and H are equally frequent.

### 4.1.4 A simple model

As a first-pass assessment of the grammar, I trained a model to see if the proposed constraints can be weighted so as to accurately frequency-match the metrical corpus. This naive model assumes that if the poets had no gradient metrical preferences, any of the 1024 possible patterns would come up equally likely. Table 4.3 shows the weights obtained in the model, as well as the results of a model selection procedure using $\mathrm{AIC}_{\mathrm{c}}$ (see $\S 3.3 .3 .1$ for discussion). The $\operatorname{AIC}_{c} \Delta$ values show the difference between the $\mathrm{AIC}_{\mathrm{c}}$ of the full grammar and a simpler grammar where the constraint in question is omitted (that is: $\mathrm{AIC}_{\mathrm{c}} \Delta=\mathrm{AIC}_{\mathrm{c}_{\text {model without constraint }}-\mathrm{AIC}_{\mathrm{Cfull} \text { model }} \text { ). The evidence ratio expresses }}$ how relatively more likely the full grammar is, compared to the simpler one. As the table shows, in each case the full model is much more likely than the simpler one, offering strong evidence that all five constraints play an important role in the proposed grammar. Unsurprisingly, *SQUEEZE(R, Colon) was weighted negatively.


Figure 4.4: Scattergram for trochaic tetrameters: predicted vs. observed line counts

Figure 4.4 plots the results in a scattergram, showing the predicted counts of each pattern versus the observations. The fit is almost perfect: most of the dots are close to the regression line, which is nearly diagonal, and the coefficient of determination is also high $\left(R_{a d j}^{2}=0.978\right)$. The model also correctly predicts that most candidates are unattested, as the cluster of dots in the bottom left corner shows. Descriptively speaking, then, this simple model of the tetrameters is accurate.

### 4.1.5 Cross-validation

Although the above analysis seems to be on the right track, different results might have been obtained with a different data sample - in other words, we do not know how well the model generalizes to unseen data. To assess generalization performance, I used n-fold cross-validation, as described in §3.3.3.1. The results of the validation ( 3 folds, 10 iterations) are shown in the boxplot (e.g. McGill et al. 1978) in Figure 4.5. As the figure reveals, the constraint weights did not vary much in each iteration, and were close to the numbers obtained in the simple model. The mean $R_{a d j}^{2}=0.927( \pm 0.036)$


Figure 4.5: Boxplot for the trochaic tetrameter model cross-validation
was also high, suggesting that the model approximates the metrical grammars of the included authors rather well.

### 4.1.6 A baseline model

As pointed out in $\S 3.3 .4$, it does not seem plausible to assume that poets would choose patterns from the sample space a priori equally probably, since the Greek language delivers to the poets some patterns more likely than others. This section describes models that try to incorporate such prior linguistic information, using the procedures introduced and discussed in §3.3.4. First, I generated a 20000 -line random trochaic tetrameter corpus, which includes nonsense lines such as these:
(8) toîs I ólaon anth' etaírās hōs hékastai philtaton

H LLLL H LH H H LH H HLH
prāgmátōn holoskherôs ek tâs égōoudè Lūdían
H LH LH LH H H LH L HLH
Kerkuraion nautikôi dè katano ésasa ksénon
H LHH H LH L LL LHLH L H

In addition to requiring that the pseudo-lines obey the inviolable pattern constraints defined in §4.1.3.1 above, I only selected lines that have an orthographic word-break

| Constraint | Weight | Baseline weight | Difference |
| :--- | ---: | ---: | ---: |
| STRONG $\Rightarrow$ LONG | 2.84 | 0.93 | 1.91 |
| SUPERSTRONG $\Rightarrow$ LONG | 1.53 | 0.22 | 1.31 |
| STRONG $\Rightarrow$ LONG(Clausula) | 1.09 | 0.05 | 1.04 |
| *SQUEEZE(Clausula) | 0.53 | -0.24 | 0.77 |
| *SQUEEZE(R, Colon) | -0.83 | -0.73 | -0.10 |

Table 4.6: Constraint weights for trochaic tetrameters: baseline vs. simple
after the first colon, just like the real lines do in my dataset. ${ }^{7}$ In the first test, I trained a Maxent model on the random corpus, using the five metrical constraints from the above analysis. The fitted weights are given in Table 4.6. The Difference column shows the result of subtracting each weight obtained in the fitted random corpus from its "real" value obtained in the simple model (see §4.1.4 above).

Just like in the simple model, Strong $\Rightarrow$ Long obtained the highest weight (0.93); this is not surprising, given that the sequence LL is, overall, less frequent than H in Greek (e.g., O’Neill 1939). Superstrong $\Rightarrow$ Long and Strong $\Rightarrow$ Long(Clausula), however, had low weights ( 0.22 and 0.05 , respectively), which gives some support for the intentionality of the metrical properties they represent. Note also that *Squeeze(Clausula) received a slightly negative baseline weight (-0.24), which suggests that its positive weight $(0.53)$ was not obtained by accident in the real model. In general, all constraints-except the dubious * $\operatorname{SqUEEZE}(\mathrm{R}$, Colon)—received higher weights in the simple model versus the baseline model, indicating that these constraints express true metrical preferences of the poets instead of reflexes of Greek vocabulary and grammar. The simple-baseline difference of *Squeeze(R, Colon) was still slightly negative at -0.10 .

[^38]| Constraint | W | Baseline W | Diff. | AIC $_{c} \Delta$ | Evidence ratio |
| :--- | ---: | ---: | ---: | ---: | ---: |
| STRONG $\Rightarrow$ LONG | 2.84 | 1.18 | 1.67 | 314.33 | $>10000$ |
| SUPERSTRONG $\Rightarrow$ LONG | 1.53 | 0.24 | 1.29 | 23.34 | $>10000$ |
| STRONG $\Rightarrow$ LONG(Clausula) | 1.09 | 0.06 | 1.03 | 10.96 | 240.26 |
| *SQUEEZE(Clausula) | 0.53 | -0.17 | 0.67 | 49.57 | $>10000$ |
| *SQUEEZE(R, Colon) | -0.83 | -0.74 | -0.09 | 1.13 | 1.76 |

Table 4.7: Constraint weights for trochaic tetrameters: baseline vs. simple ( $\mathrm{AIC}_{\mathrm{c}}$ comparison)

However, it does not suffice to list the differences between the two models' weightswe also want to see if the differences are meaningful. To that end, I performed the following trials (for the details, see §3.3.4). First, I fitted the model $k$ times ( $k$ being the number of constraints, five in this case), and in each iteration $i$, replaced the default Gaussian prior $\left(\mu_{i}=0, \sigma_{i}^{2}=1\right)$ of the $i$ th constraint with $\mu_{i}=$ baseline weight, $\sigma_{i}^{2}=$ 0.001 , which almost (but not quite) fixes the constraint's weight to its prior $\mu$ value. ${ }^{8}$ Then, I used $\mathrm{AIC}_{\mathrm{c}}$ to compare the simple model (that is, the one with the uniform priors described §4.1.4 above) with each of the $k$ models that employ the baselinepriors for each individual constraint. Of interest are, again, the $\Delta$ values and evidence ratios, which can give quantitative evidence for or against either of the models under comparison.

The results are shown in Table 4.7. The high evidence ratios confirm that $\quad$ Strong $\Rightarrow$ Long, $\quad$ Superstrong $\Rightarrow$ Long, $\quad$ Strong $\Rightarrow$ Long(Clausula) and *Squeeze(Clausula) are, based on the evidence, true metrical preferences, even when the lexical statistics of Greek are taken into account. By contrast, in the model comparison where *SQuEEzE(R, Colon) had to compete with its baseline-prior, the evidence for the prior-less model was just 1.76, a negligible difference. In other words, there is no convincing evidence that the unnatural constraint *SQuEEzE(R, Colon) invokes real metrical preference; the second anceps is truly "free".


Figure 4.8: Boxplot for shuffled trochaic tetrameters

### 4.1.7 Restrictiveness

Finally, we should address the possibility that the preference constraints used in the preceding analysis could be fitted to any data. After all, the weights can be set to any arbitrary value, which at first view might suggest that, given suitable weights, the constraints could accurately predict completely arbitrary probability distributions of possible line types. To test for that possibility, I SHUFFLED the empirical frequency distribution by randomly switching the frequencies of each possible pattern with some other pattern, so that, for instance, some zero-frequency patterns get a non-zero frequency, and vice versa. I shuffled the data and fitted the model 10 times, retaining the constraint weights from each iteration. The results, which are reported in Figure 4.8 , effectively falsify the hypothesis that the constraints could model any data: the weights are highly spread, often (nonsensically) negative, and the average value of $R_{a d j}^{2}$ is practically zero $(-0.005 \pm 0.004)$.

[^39]
### 4.1.8 A note on performance

Ancient testimony provides some indirect support for the idea that H syllables in ancipitia are "squeezed" to a single gridmark in trochaic tetrameters. First, according to Aristotle, the meter is most suitable for dancing (Poetics 1449a and 1460a; Rhetoric 1409a); other sources call the meter khoréios "belonging to dance" (e.g., Pseudo-Plutarch, On Music 1141b). The word trokháios, on the other hand, means "running" (LSJ, s.v.), which some ancient authors associate with a fast recitation tempo (e.g., Aristotle, Rhetoric 1409a; Aristides Quintilianus, On Music 1.16). The material that survives is compatible with a fast pace, as the lines typically deal with excitement or lively situations (Drew-Bear 1968, Devine and Stephens 1994, p. 116). ${ }^{9}$ The association with dancing and running is, arguably, more compatible with an isochronous than an anisochronous rhythm.

### 4.1.9 Summary

On the analysis offered here, the trochaic tetrameter catalectic is based on a grid structure with periodically alternating strong and superstrong levels of prominence. Poets map H syllables to superstrong positions more often than to strong positions, and the gridmark preceding a superstrong position is required to be filled with L . The trochaic tetrameter has eight strong positions, four of which are additionally superstrong. Towards the ends of lines, final strictness constraints are observed both with regard to squeezing and resolution, making lines more regularly trochaic near the end. A model that included a baseline probability for each possible pattern indicated that the included constraints seem to express true metrical preferences-except for the unnatural constraint that ostensibly rewards squeezing in the final position of the first colon, whose effect was explained by the baseline alone.

[^40]
### 4.2 Iambic trimeter

The basic quantitative schema of the Archaic and tragic iambic trimeter is the following:


The schema is essentially the same as that of the trochaic tetrameter catalectic, minus the first three positions (West 1982a, p. 40). The caesura after the second anceps corresponds to the location of the obligatory colon boundary in the trochaic tetrameter; and both meters avoid word-breaks after the final anceps (ibid.). Resolution of nonfinal principia, while allowed, is rare in both meters. The main differences are that the trimeter allows the first position to be realized as LL (indicated above with the symbol $\breve{\times}$ ), as well as the postponement of the main caesura by two (or more rarely, one) positions. ${ }^{10}$

Here are some example lines from Sophocles' Electra (1-3):
(10) Ô toû stratēgésantos en Troíai potè

H H LHHH L|H HH LH
"Son of our army's commander once in Troy,"
Agamémnonos pâ̂, nûn ekeîn' éksestí soi
L L H L H H| H LH H H L H
"of Agamemnon, now it's your time"
parónti leússein, ôn próthumos êsth' aeí

"to look at the things that have always been close to your heart"

### 4.2.1 The data

The dataset under analysis comprises all surviving iambic trimeters by the three Archaic poets Archilochus, Solon and Semonides, as well as a 500 -line random sample from each of the three tragedians. In total, the dataset has 3274 lines. Figure 4.9 shows the relevant data.

[^41]

Figure 4.9: Syllable types in iambic trimeters

Resolution is rare: on average only $2.1 \%$ of principia are resolved. It is most common in the first $(2.2 \%)$ and third $(6.1 \%)$ feet, less common in the second and fourth feet (both $2 \%$ ), and almost completely avoided in the fifth foot $(0.2 \%)$. The figures are close to those of the corresponding positions of the trochaic tetrameters (§4.1.1). Similarly, ancipitia on average are more often H than $\mathrm{L}(56.9 \%)$; but this is much rarer in the final anceps (41\%) than in the first two ancipitia (64-65\%). Finally, though lines are permitted to start with LL, only $2 \%$ of them do in my dataset.

### 4.2.2 Metrical structure

The obvious parallels between the trochaic tetrameter and iambic trimeter indicate that they are based on the same basic structure. If the trochaic tetrameter catalectic derives from a headless iambic tetrameter (see §4.1.8), then it could be conjectured that the iambic trimeter is a further step in the derivation, with the entire first metron truncated (Kiparsky 2018, p. 100). But while the trochaic tetrameters have (as argued above) a $8+7$ structure, with a possible pause or final lengthening at the end to signal couplet boundary, there is no evidence for pauses between iambic trimeter lines; on the contrary, tragedies in particular have many run-on lines that suggest a fairly rapid recitation style. According to an alternative derivation, the iambic trimeter originates in an octosyllabic pattern, which would also have been the $u r$-source of the trochaic tetrameter: the former extends it by one metron and the latter by two (West 2007, p. 49 ; see also §5.1.1).

Just like trochaic tetrameters, iambic trimeters have regular phrasal breaks that do not match the iambic metron boundaries. (11) shows the metrical grid with the two most common colon alternatives (first row of brackets: "early caesura", second row: "late caesura"):


If the above grid structure is correct, the superstrong grid columns should again align more strictly with H syllables than strong columns do. In addition, in light of the preceding analysis of trochaic tetrameter, it would be favorable for the analysis if the ostensible preference for squeezing in some of the ancipitia emerged as an unintentional lexical effect. The following sections demonstrate that the data is indeed compatible with such analysis.

### 4.2.3 Constraints

### 4.2.3.1 Pattern constraints

The pattern constraints for iambic trimeter are much the same as those for trochaic tetrameter: ${ }^{*}$ Squeeze $\neg\left(\mathrm{L}\right.$, Metron), ${ }^{*}$ Float, ${ }^{*}$ Stretch, and Long $\Rightarrow$ Strong, ${ }^{11}$ as well as *Empty. The option to start lines in LL could be analyzed in different ways. The extra L might be considered extrametrical (a *FLOAT violation), but in that case, an additional constraint would be needed to explain why the extrametrical L cannot be followed by a heavy anceps. It thus seems simpler to analyze the extra $L$ as mapped to the first position, violating *CrowD ("One syllable per grid position"). In order for lines to be able to violate *CROWD only line-initially, however, a relevant initial laxness constraint needs to be invoked (on such licensing constraints, see §4.1.3.1 above). Let us call this one ${ }^{*} \operatorname{CROWD} \neg(\mathrm{~L}$, Line $)$, or "No crowding, except at the left edges of lines".

[^42]| Constraint | Weight | AIC $_{\mathrm{c}} \Delta$ | Evidence ratio |
| :--- | ---: | ---: | ---: |
| Strong $\Rightarrow$ Long | 3.15 | 6833.97 | $>10000$ |
| Strong $\Rightarrow$ Long(Clausula) | 2.88 | 179.50 | $>10000$ |
| *Crowd | 2.74 | 1285.06 | $>10000$ |
| *SQUEEZE(Clausula) | 0.96 | 488.17 | $>10000$ |
| SUPERSTRONG $\Rightarrow$ LoNG | 0.73 | 47.90 | $>10000$ |
| *SQUEEZE | -0.60 | 546.27 | $>10000$ |

Table 4.10: Constraint weights for iambic trimeters: simple model

Using these constraints, the possible number of line types is 384 , out of which 81 have a non-zero frequency in my data sample.

### 4.2.3.2 Preference constraints

In addition to *Crowd (see above), the model will include the preference constraints $\operatorname{Strong} \Rightarrow$ Long, Strong $\Rightarrow$ Long(Clausula), and Superstrong $\Rightarrow$ Long, whose definitions were given in §4.1.3.2. To model squeezing, first, I again use *Squeeze(Clausula), which penalizes H in the last anceps. In the first two ancipitia, as noted above ( $\S 4.2 .1$ ), squeezing is the more common option, just as was the case with the second anceps in the trochaic tetrameters. To keep things simple, I use the general *Squeeze constraint (defined in §3.4.1) to model this observation-a violation will be incurred whenever a H is mapped to any of the three ancipitia.

### 4.2.4 A simple model

The constraints were again weighted using Maxent, at first pass using only empirical data and no baseline. Table 4.10 shows the obtained weights and the results of an $\mathrm{AIC}_{\mathrm{c}}$ model comparison. As expected, there was strong evidence for each of the six constraints; and just as in the trochaic tetrameters, the prominence mapping constraint Strong $\Rightarrow$ Long is weighted higher than the more specific Strong $\Rightarrow$ Long (Clausula) and Superstrong $\Rightarrow$ Long constraints of the same family. Unsurprisingly, *Squeeze


Figure 4.11: Scattergram for iambic trimeters: predicted vs. observed line counts
had a reversed-sign weight. ${ }^{12}$ Figure 4.11 visualizes the model's predictions on a scattergram, displaying practically no outliers and an almost perfect correlation $\left(R_{a d j}^{2}=\right.$ 0.994). Based on these results, it may be concluded that the six constraints do a good job in modeling this particular dataset.

### 4.2.5 Cross-validation

I also assessed model generalization performance using cross-validation, as in the previous analysis of the trochaic tetrameters. Figure 4.12 plots the results of a 3 -fold cross-validation, with 10 iterations. The constraint weights were very consistent across the folds, and the mean values close to the values obtained with the full corpus. The average value of $R_{a d j}^{2}=0.988( \pm 0.005)$ was also high, indicating that the model generalizes just fine.

[^43]

Figure 4.12: Boxplot for the iambic trimeter model cross-validation

### 4.2.6 A baseline model

The next step is to test the extent to which the selected constraints express true metrical preferences, instead of being just reflexes of a priori patterns of the Greek language. I again generated a corpus of 20000 pseudo-lines, $80 \%$ of which have an "early" caesura and $20 \%$ a "late" one, mirroring the statistics of my real dataset. All included lines respect the pattern constraints of $\S 4.2 .3 .1$. Here are some examples:

## kōlúomen ei ex Aphrodítēs Argunnídos

H LL L H H L LLH H LH
mèn émérōs te eîma peribalómenos hōs
L H LH LH L LLLL LL H
égrapsen estin di ábathron leptòn forê̂
L H L H H LL L H H H LH

Using the same procedure as above (§4.1.6), I fitted a model including the six preference constraints to the random lines, retained the obtained weights, and used them-one by one - as baseline-priors for the constraints modeling the real data. Table 4.13 reports the differences between the real weights and the baseline weights, as well as the relevant $\mathrm{AIC}_{\mathrm{c}}$ model comparison data. The results are again illuminating. There is convincing evidence (subject to the limitations of the baseline model) that

| Constraint | W | Baseline W | Diff. | $\mathrm{AIC}_{\mathrm{c}} \Delta$ | Evidence ratio |
| :--- | ---: | ---: | ---: | ---: | ---: |
| Strong $\Rightarrow$ Long | 3.15 | 1.70 | 1.46 | 872.90 | $>10000$ |
| Strong $\Rightarrow$ Long(Clausula) | 2.88 | 0.13 | 2.74 | 157.40 | $>10000$ |
| *Crowd | 2.74 | 0.88 | 1.86 | 457.03 | $>10000$ |
| *SQUEEZE(Clausula) | 0.96 | 0.51 | 0.45 | 107.55 | $>10000$ |
| Superstrong $\Rightarrow$ Long | 0.73 | 0.28 | 0.46 | 17.21 | 5447.63 |
| *SQueEze | -0.60 | -0.56 | -0.04 | 0.09 | 1.04 |

Table 4.13: Constraint weights for iambic trimeters: baseline vs. simple ( $\mathrm{AIC}_{\mathrm{c}}$ comparison)
the included constraints are not due to lexical statistics alone - except for *Squeeze, for which there is basically no support (evidence ratio 1.04). Just like in the trochaic tetrameters, the "preference" for squeezing is illusory, in the light of the present analysis.

### 4.2.7 Restrictiveness

Last, I assessed the restrictiveness of the analysis by shuffling and fitting the data 10 times, as in §4.1.5 above. To save space, the weights are not plotted here - instead, I give the following summary measures: the mean of the means of all constraint weights was $0.06( \pm 0.17)$, the mean of their standard deviations $0.77( \pm 0.24)$, and the mean $R_{\text {adj }}^{2}$ values $0.02( \pm 0.01)$. Expressed verbally, the weights were dispersed around zero (roughly between 1 and -1 ) with a practically non-existent fit to the data. It is then evident that the constraints cannot be used to model any arbitrary data.

### 4.2.8 Notes on performance

Not much can be said about the rhythms of iambic trimeters in performance. The normal way of delivery may have been rhythmically closer to speech than song; Aristotle famously says that the trimeter is the "most conversational" of the meters and that "in talking to each other we most often use iambic lines" (Poetics 1449a). As the main dialogue meter of both tragedy and comedy, it would probably have had more rhythmic freedom in performance than the meters that are associated with singing or dancing.

|  | Sentence end | No sentence end | Ratio | Odds ratio | p-value |
| :--- | ---: | ---: | ---: | ---: | ---: |
| Early caesura | 805 | 1750 | 0.46 |  |  |
| Late caesura | 449 | 751 | 0.60 | 1.30 | 0.0004 |

Table 4.14: Comparison of line-endings and caesuras in iambic trimeters

One ancient source, however, testifies that in some cases, iambic trimeters could be sung with instrumental accompaniment (Pseudo-Plutarch, On music 28).

Table 4.14 shows data that are of some preliminary interest for a future study of the performance rhythms of the iambic trimeter. The table compares tallies of lineendings that correspond with a sentence end in lines that have an "early" vs. a "late" caesura. Recall that by early caesura is meant the most common break after the first anceps and by late caesura a break two (or rarely, one) positions later. Sentence and line-ends coincide somewhat more often in lines with late caesura (odds ratio 1.30); and the low p-value of the chi-squared statistic (e.g., Agresti 2007, Section 2.4) indicates that the difference is not likely to be due to chance. Although the result would need to be controlled for confounding factors, it can be conjectured that what we see here is a saliency effect (see §1.3.6): lines with a late caesura are better for period-endings because they are structurally long colon first, short colon last, whereas lines with an early caesura have the opposite structure. This idea is illustrated in (13).
(13) a. $\times-\cup-\times$ |
$-\cup-\times-\cup-$
b. $x-v-x-u$
-× - -
early caesura: non-salient
$-$

Hypothetically, if the iambic trimeters were based on such a colon structure, in lines with an early caesura there could have been a slight pause or lengthening after the caesura (i.e., after the 2nd anceps), whereas in late-caesural lines the pause would occur at the end of the line. Some support for this can be found by comparing the frequencies of H vs. L in the second anceps with the different caesuras. The relevant data are given in Table 4.15 and Table 4.16.

Table 4.15 shows that in lines that have an early caesura, the 2 nd anceps is realized with a heavy syllable 3.48 times as often as in lines with an early caesura (p-value

|  | H in 2nd anceps | L in 2nd anceps | Ratio | Odds ratio | p-value |
| :--- | ---: | ---: | ---: | ---: | ---: |
| Early caesura | 1884 | 671 | 2.81 |  |  |
| Late caesura | 536 | 664 | 0.81 | 3.48 | $<0.0001$ |

Table 4.15: Values of 2 nd anceps in iambic trimeter lines with early vs. late caesura

|  | H $\mid$ in 2nd anceps | L $\mid$ in 2nd anceps | Ratio | Odds ratio | p-value |
| :--- | ---: | ---: | ---: | ---: | ---: |
| Early caesura | 1884 | 671 | 2.81 |  |  |
| Late caesura | 144 | 162 | 0.89 | 3.16 | $<0.0001$ |

Table 4.16: Values of 2 nd anceps, with word-break, in iambic trimeter lines with early vs. late caesura
$<0.0001) .{ }^{13}$ As such, the result does not mean much, since all early caesuras by definition correspond with a word-end at the 2nd anceps, and the greater frequency of H could follow from this alone. Let that then be a null hypothesis. Table 4.16 shows the same comparison with the added criterion that both types of line have a word-end at the 2 nd anceps. The ratio of $\mathrm{H}: \mathrm{L}$ is still 3.16, indicating that the null hypothesis can be rejected. While even these results would need statistical controlling, they can be provisionally taken to support the idea pictured in (13) above.

### 4.2.9 Summary

On the present analysis, the quantitative pattern of the iambic trimeter is based on the same basic iambic cycle as the trochaic tetrameter, with two prominence levels. A metrical corpus was modeled using six preference constraints that refer to the groups and intersecting periodicities of the grid. The constraints modelled the data accurately both in a simplistic analysis without a baseline and with a prose baseline model. Just as in the trochaic tetrameters, the models suggest that although H syllables are squeezed to some weak positions more often than not, this stems from purely linguistic factors rather than from a metrical preference. Last, some preliminary evidence was given in support of a hypothesis that the main caesura of a trimeter line is related to saliency:

[^44]lines with an early caesura have fewer sentence ends and a $5+7$ structure（non－salient）， whereas late－caesural lines have more sentence ends and a $7+5$ structure（salient）．

## 4．3 Comic iambic trimeter

Athenian comic poets used a freer version of the iambic trimeter than the Archaic and tragic poets（West 1982a，p．88）．A major difference in their quantitative patterning is that in the comic version the $\smile$ and $\times$ positions can be alternatively realized as $\cup \checkmark$ ．The schema is as follows：

The meter is also freer as regards phrasing：caesuras are not required，and the Archaic and tragic ban on word－end after the 3rd anceps（Porson 1802，p．xxx）is here relaxed．To illustrate，here are some randomly chosen lines（Aristophanes，Wasps 103－105）：
euthùs d＇apò dorpēstô̂ kékrāgen embádas， H H L L H H H L HL H L H
＂Right after supper，he yells for shoes，＂
kápeit＇ekeîs＇elthò̀n prokatheúdei pròi pánu， $\begin{array}{lllllllllll}H & H & L & H & H & L & H & H & H & H\end{array}$ ＂and dashes down there to sleep in the wee hours，＂ hósper lepàs prosekhómenos tôi kí⿳亠二口欠oni． H H L H L L L HL H H LH
＂clinging to the column like an oyster．＂

## 4．3．1 The data

For this study，I scanned all iambic trimeters from two Aristophanean comedies，The Wasps and The Clouds，totaling to 1486 lines．The data are shown in Figure 4．17．As can be seen，despite the allowed freedoms of the comic variant，lines still tend to be rhythmically regular：most principia are realized as H （on average $90 \%$ of non－final positions）and $\smile$ are most commonly $\mathrm{L}(92 \%)$ ；and LL is avoided in general（ $8 \%$ of all non－final positions）．Visual inspection of the chart shows also that final strictness is in effect here：the LL line goes down and the H and L lines go up．


Figure 4.17: Syllable types in comic iambic trimeters

### 4.3.2 Metrical structure

I will assume that even this freer variant is based on the iambic metron with strong and superstrong levels, as visualized in (5) and reproduced below in (16). The meter then consists of three such metra.

|  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $x$ |  |  |  |  |  |  |
|  | $x$ |  |  |  |  |  |  |
| $x$ | $x$ | $x$ | $x$ | $x$ | $x$ |  |  |
| $X$ | $H$ |  | $L$ | $H$ |  |  |  |

### 4.3.3 Constraints

### 4.3.3.1 Pattern constraints

The pattern constraints are the same as in the Archaic and tragic trimeter, with one exception. To allow the mapping of LL to the resolvable anceps ( $(\underset{\times}{*})$ and short ( $(\underset{y}{*}$ ) positions, we need some additional licensing constraint. Somewhat arbitrarily, I will model them as the permission to "crowd" syllables at foot beginnings, or *CrowD $\neg(\mathrm{L}$, Foot): "No crowding, except at the left edges of feet". This is a laxer version of the constraint ${ }^{*}$ CROWD $\neg(\mathrm{L}$, Line), by which I analyzed the crowding of L syllables at the beginning of lines in the non-comic iambic trimeters (see §4.2.3.1). Though *CrowD $\neg($ L, Foot $)$ is arbitrary it helps keep the Maxent analysis simple; an alternative (and possibly more realistic) analysis will be discussed in $\S 4.3 .8$ below. Using these
constraints, the number of possible lines is 6912 , of which just 237 are attested in my dataset.

### 4.3.3.2 Preference constraints

The preference constraints, too, are much the same as in Archaic and tragic trimeters: Strong $\Rightarrow$ Long, $\quad$ Strong $\Rightarrow$ Long(Clausula), $\quad$ Superstrong $\Rightarrow$ Long, $*$ Squeeze, *Squeeze(Clausula), *Crowd. As discussed above, *Crowd will not only penalize line-initial LL but all mappings of LL to $\breve{\times}$ or $\breve{\sim}$. In addition, I add the constraint ${ }^{*}$ Crowd (Clausula), which will model the increasing rarity of the crowding of Ls towards the end of the line (see Figure 4.17 above for justification).

### 4.3.4 A simple model

The weights obtained from training a simple Maxent model are shown in Table 4.18, and Figure 4.19 is the corresponding scattergram. Judging by the weights, the preferences that stand out are the avoidance of crowding and resolution-which is to say that LL is avoided everywhere (and especially in the clausula, as the high weights of ${ }^{*}$ Crowd (Clausula) and $\operatorname{Strong} \Rightarrow \operatorname{Long}(C l a u s u l a)$ indicate). The evidence for SUPERSTRONG $\Rightarrow$ Long, however, turns out to be weak (evidence ratio 2.04), suggesting that the hypothetical superstrong level of metrical prominence does not find much support here. *SQuEEzE, as expected, gets a negative weight. The scattergram shows that the model achieves a good fit to the data; most dots lie close to the diagonal line, and the $R_{a d j}^{2}$ value is high (0.92). Yet, compared to the scattergram of the non-comic trimeters (Figure 4.11) the dots are more dispersed, reflecting the greater rhythmic variability of the comic variant.

### 4.3.5 Cross-validation

Figure 4.20 shows the results of a 3 -fold cross-validation with 10 iterations. The mean $R_{a d j}^{2}=0.861( \pm 0.028)$ of the trials was adequate, and the weights were relatively stable across the iterations. The predictive accuracy of the grammar thus appears to be acceptable.

| Constraint | Weight | $\mathrm{AIC}_{\mathrm{c}} \Delta$ | Evidence ratio |
| :--- | ---: | ---: | ---: |
| *CROWD(Clausula) | 1.99 | 288.82 | $>10000$ |
| STRONG $\Rightarrow$ LONG | 1.95 | 1884.65 | $>10000$ |
| *CROWD | 1.78 | 2322.86 | $>10000$ |
| STRONG $\Rightarrow$ LONG(Clausula) | 1.70 | 144.74 | $>10000$ |
| *SQUEEZE(Clausula) | 0.41 | 39.37 | $>10000$ |
| SUPERSTRONG $\Rightarrow$ LONG | 0.15 | 1.43 | 2.04 |
| *SQUEEZE | -0.59 | 244.06 | $>10000$ |

Table 4.18: Constraint weights for comic iambic trimeters: simple model


Figure 4.19: Scattergram for comic iambic trimeters: predicted vs. observed line counts


Figure 4.20: Boxplot for the comic iambic trimeter model cross-validation

### 4.3.6 A baseline model

A baseline language model was again used to factor out the non-metrical linguistic elements from the analysis. Here are some examples from the 20000 -line pseudocorpus:
odoû esépesen és te makhessámeth' eíneka
L H LLLL H L L H L L H L H
oud' ekséteina kheîr' apomózdōn emè̀n
H H LH L H L H H H L H
euergétan aganaîs kharítessin bastásai
HH LH LLH LLH H H LH

To approximate the real data, I accepted any line that respects the pattern constraints (§4.3.3.1) as metrical, without any constraints on phrasing. The results of the model comparisons using baseline-priors vs. uniform priors (as in §4.1.6 and §4.2.6 above) are given in Table 4.21. As the evidence ratios indicate, the results are similar to those attained from the simple model: there is considerable evidence for all constraints except SUPERSTRONG $\Rightarrow$ LONG, which means that there is, indeed, no convincing support for the two-level metrical hierarchy in the comic trimeters. Moreover, the evidence for the reversed-sign weight of ${ }^{*}$ SQUEEZE is compelling (with a 125:1 ratio in favor of

| Constraint | W | Baseline W | Diff. | $\mathrm{AIC}_{\mathrm{c}} \Delta$ | Evidence ratio |
| :--- | ---: | ---: | ---: | ---: | ---: |
| *Crowd(Clausula) | 1.99 | 0.36 | 1.63 | 180.23 | $>10000$ |
| Strong $\Rightarrow$ LonG | 1.95 | 1.39 | 0.57 | 117.20 | $>10000$ |
| *Crowd | 1.78 | 1.20 | 0.58 | 192.65 | $>10000$ |
| Strong $\Rightarrow$ Long(Clausula) | 1.70 | 0.11 | 1.59 | 123.80 | $>10000$ |
| *SQuEEZE(Clausula) | 0.41 | 0.12 | 0.29 | 18.42 | $>10000$ |
| Superstrong $\Rightarrow$ Long | 0.15 | 0.11 | 0.04 | 1.80 | 2.46 |
| *SQueEze | -0.59 | -0.46 | -0.13 | 9.66 | 125.30 |

Table 4.21: Constraint weights for comic iambic trimeters: baseline vs. simple ( $\mathrm{AIC}_{\mathrm{c}}$ comparison)
the real model), as opposed to the trochaic tetrameter and non-comic iambic trimeter, where the baselines alone looked to be responsible for the "preference" for squeezing. The implication is that Aristophanes truly prefers squeezing in the first two ancipitia. It should be noted, however, that the additional negative weight of *Squeeze, compared to its baseline-prior, is just 0.13 , so that the preference seems to be rather weak.

### 4.3.7 Restrictiveness

I shuffled the data-that is, reorganized the corpus frequencies randomly-10 times to see if the grammar could be weighted to model any data. The results speak firmly against that hypothesis: the weights hover around zero (mean of means $0.002 \pm 0.58$ ), roughly between -0.5 and 0.5 (mean of standard deviations $0.33 \pm 0.11$ ), with a nearzero $R_{\text {adj }}^{2}=-0.003( \pm 0.001)$.

### 4.3.8 An alternative analysis of resolved Ws

In the above analysis, the mapping of LL to $\breve{\times}$ and $\breve{\sim}$ positions was treated as the crowding of $L$ syllables at left edges of feet, arbitrarily licensed by *Crowd $\neg$ (L, Foot). This section outlines an alternative analysis. Suppose it is not the breves and ancipitia that accommodate the extra Ls by line-internal crowding, but the principia that precede them. Or, expressed in terms of grids, that the extra Ls are mapped to the grid column which is normally filled with the second mora of the preceding H syllable-like this:

$$
\begin{array}{llllll} 
& & & & & x  \tag{18}\\
& x & & & x & \\
x & x & x & x & x & x \\
X & H & L & L & H &
\end{array}
$$

An interesting clue which seems to support (18) is that the extra $L$ syllables are only allowed when the preceding princeps is realized as $H$ (West 1982a, p. 88), with very few exceptions (just 8 in my dataset). At first pass, this looks like a ${ }^{*}$ LLL effect (see $\S 3.4 .4$ ), since the banned configuration would produce a sequence of Ls, something that Greek poets generally avoid. But crucially, the same restriction is much less rigid when the LL stands in a resolved S : in my comic trimeter corpus there are 253 occurrences of LLLL when they are mapped $\underset{\mathrm{L}}{\mathrm{W}} \stackrel{\mathrm{S}}{\mathrm{L}} \underset{\mathrm{L}}{\mathrm{L}}$, which is almost as common as HLLL mapped the same way (263 occurrences).

There must then be some other reason for the semi-ban on $\stackrel{S}{L} \underset{L L}{W}$. The proposed mapping in (18) provides one: it is certainly less disruptive rhythmically to treat a H "as if" it was L than to align four Ls with three gridmarks. In addition to this conceptual argument, there is some empirical evidence to support (18). It is well known (e.g., Selkirk 1995) that so-called function words (i.e., nonlexical words) are prosodically less stable than lexical words; and as such, they would also be more liable to squeezing. Consequently, if it was found that the H syllables in the mapping $\underset{\underset{\mathrm{H}}{\mathrm{H}} \mathrm{W}}{\mathrm{W}}$ belonged more often to function words compared to H syllables in those mappings of HLL where the H consumes two gridmarks, that would lend some support for the present proposal. In the comic trimeter, a HLL can be mapped to the grid in three ways: 1) W S 2 ) $\begin{array}{l}\text { S W } \\ \mathrm{HLL}\end{array}$ or 3$\left.) \underset{\mathrm{S}}{\mathrm{H}} \mathrm{L} \underset{\mathrm{L}}{\mathrm{L}} \mathrm{L}\right]$. It is the last two configurations that are of interest here: both map the H to a S position, but in $\underset{\mathrm{S}}{\mathrm{H}} \mathrm{W} \mathrm{H}$ uses two gridmarks, whereas in $\underset{\mathrm{H}}{\mathrm{H}} \mathrm{W} \underset{\mathrm{L}}{\mathrm{L}}[\mathrm{L}]$ it is "squeezed" (on the present proposal) to just one.

Table 4.22 compares the category of the word (nonlexical/lexical) to which the H syllable belongs to in $\stackrel{\mathrm{S}}{\mathrm{HLL}}$ vs. $\stackrel{\mathrm{S}}{\mathrm{H}} \mathrm{HL} \underset{\mathrm{L}}{\mathrm{S}} \mathrm{S}]$. The data comes from the same 1486 line corpus that I used in the Maxent analyses described above. I counted as lexical words nouns, adjectives and verbs, and all the rest as function words. As the table shows, H syllables are around 1.45 as likely to be in a function word when mapped to a S preceding $\underset{\mathrm{LL}}{\mathrm{W}}$, a result that tentatively supports the mapping shown in (18). This is

|  | H in nonlexical | H in lexical | Ratio | Odds ratio | p-value |
| :--- | ---: | ---: | ---: | ---: | ---: |
| H LL mapped to SW | 268 | 184 | 1.46 |  |  |
| H L LL mapped to SWS | 184 | 182 | 1.01 | 1.45 | $<0.01$ |

Table 4.22: Comparison of word category of H followed by LL in comic iambs
a very preliminary result, however, as there might well be other factors affecting the choice of lexical vs. nonlexical words in these configurations. ${ }^{14}$

### 4.3.9 Summary

Although the comic variant of the iambic trimeter is much freer than the Archaic/tragic one, it too is regular to an extent. Like many other metrical forms in Greek, the comic trimeter gets stricter towards the end of the line, avoiding squeezing, resolution of S , and the "crowding" of L syllables in W positions in the final metron. However, both my simple Maxent model and its baseline-augmented version supported a single-level prominence alternation in the comic variant, in contrast to the Archaic/tragic iambs which, according to the preceding analyses, have two (strong, superstrong). Finally, it was suggested that the apparent mapping of LL to W positions is in fact due to the mapping of HL to the preceding S .

### 4.4 Anapestic dimeter

The bulk of ancient Greek anapests come from dramas (for the rest, see West 1982a, pp. 53-54) and there we find two distinct types: 1) so-called Recitative anapests, which were primarily associated with the chorus and its movements onstage, and 2) MELIC anapests, which are thought to have been sung by the actors ( $\mathrm{mélos}=$ "song", LSJ, s.v.). Both types are based on the anapestic metron (Schol. B. in Heph. 15, Consbruch 1906, p. 275), which can be schematized as follows:

[^45]The metron has four metrical positions, any of which can be either H or LL (except the line-final position which is always H due to brevis in longo; see §1.3.2). Anapestic verse is usually composed in periods of between one and four metra, commonly with a word-break at each metron boundary. In comedy, the most common recited type is a four-metron line (tetrameter), with a catalectic and more regular final metron $\cup \checkmark$ $-_{\wedge}$. Tragic recitative anapests are composed in longer and more irregular periods, where various numbers of dimeters (as well as occasional monometers) are followed by the catalectic metron. ${ }^{15}$ In this section, I focus on the (non-catalectic) dimeter parts of those periods. Anapests are named after the anapestic foot (LLH); but as Golston and Riad (2000, p. 116) point out, the anapestic foot is actually only the second most common foot after the spondee (HH) in the extant texts. HLL is also common in the anapests, and very sporadically we also encounter LLLL. Here are some example lines from Euripides' Alcestis (29-31):
tí sù pròs meláthrois? tí sù têide poleîs,

## $\begin{array}{lllllll}L & L & L L & H & L\end{array}$

"Why are you at the palace? What do you loiter here for,"
Phoîb'? adikeîs â̂ tīmà̀s enérōn
H LLH H H H L L H
"Phoebus? Are you again offending the gods below,"
aphorizdómenos kai katapaúōn?
L LHLLH H LLHH
"denouncing and stopping to worship them?"

The quantitative flexibility of Greek anapests presents a challenge for a metrical theory based on templates: if any of the (non-final) metrical positions can be mapped to either H or LL, can the syllabic patterns be analyzed in terms of any underlying metrical structure? In traditional metrics, the anapestic rhythm has been characterized

[^46]

Figure 4.23: Percentages of H syllables in anapestic dimeter MPs
as "rising" (i.e., from LL to H; see, e.g., Dale 1968, p. 34), but some recent critics have argued against such a characterization, noting its rhythmic variability and the fact that HH is overall more common than the canonic LLH. This section tries to show that the traditional analysis is on the right track, and that, in particular, Golston and Riad's (2000, p. 157) characterization of anapests as "quite chaotic" is unfounded.

### 4.4.1 The data

My dataset includes 1087 randomly chosen recitative anapestic dimeters ${ }^{16}$ from the Greek tragic writers Aeschylus, Sophocles and Euripides, each author representing about a third of the dataset. The percentages of H in each position are shown in Figure 4.23 . As the figure shows, H is more common than LL across the board (over $50 \%$ in every MP). It can also be seen from the upward-facing lines that H syllables are in each foot more common in odd than in even positions, which supports the traditional notion of the meter as "rising". As a preliminary statistical check, I compared the counts with the chi-squared statistic (see $\S 4.2 .8$ above), which can be used to assess the probability of the observed frequencies under the null hypothesis that they are simply due to chance. Table 4.24 shows the results of a comparison of H and LL in each odd vs. even position in a $2 \times 2$ contingency table.

[^47]| Foot | Ratios |  |  |  |
| :--- | ---: | ---: | ---: | ---: |
|  | p-value |  |  |  |
|  | H:LL (odd) | H:LL (even) | Odd:even |  |
| 1 | 2.35 | 2.72 | 1.16 | n.s. |
| 2 | 1.22 | 31.9 | 26.15 | $<0.0001$ |
| 3 | 1.96 | 2.65 | 1.35 | 0.002 |
| 4 | 1.18 |  |  | $<0.0001$ |

Table 4.24: Comparison of H:LL ratios in anapests using chi-squared test


Figure 4.25: Foot types in anapestic dimeters

The finding was that the differences between the ratios of H:LL in odd vs. even feet cannot be written off to chance, except for the first foot, where the difference is negligible. Although the result should be interpreted with caution, it does seem to give some support for the idea that the meter is rising in the traditional sense; and it is probably no coincidence that the non-significant difference is in the first foot, where metrical deviations tend to be common in meters generally (§1.3.3).

The data can also be examined at the foot level. Figure 4.25 shows the percentages of HH, LLH and HLL in each foot (LLLL is not attested in my dataset). As the chart shows, HLL is common only in the first and third feet, and practically banned elsewhere. The exclusion of HLL from foot 4 is due to brevis in longo, but the fact that it is also very rare in foot 2 ( 32 occurrences, or about $3 \%$ ) needs an explanation. Phrasing provides one: as noted above, anapests commonly align word-breaks with metron boundaries ( $95 \%$ in my dataset), suggesting that anapestic metra are not just

|  | As metron 1 |  | As metron 2 |  | All |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Count | \% | Count | \% | Count | \% |
| HH, LLH | 317 | 29.16 | 300 | 27.60 | 617 | 28.38 |
| HLL, HH | 271 | 24.93 | 298 | 27.41 | 569 | 26.17 |
| LLH, LLH | 172 | 15.82 | 199 | 18.31 | 371 | 17.07 |
| LLH, HH | 148 | 13.62 | 168 | 15.46 | 316 | 14.53 |
| HH, HH | 145 | 13.33 | 122 | 11.22 | 267 | 12.28 |
| HLL, HLL | 20 | 1.84 | 0 | 0 | 20 | 0.92 |
| others | 14 | 3.13 | 0 | 0 | 14 | 0.64 |
| total | 1087 | 1.29 | 1087 | 100 | 2174 | 100 |

Table 4.26: Metra in anapestic dimeters
rhythmic periodicities but authentic units of composition. The avoidance of HLL in the second foot may then be due to the same reason it is avoided line-finally, that is, final lengthening, pause, or some other boundary signal (see §1.3.2). In any case, Figure 4.25 makes it clear that anapestic dimeters are far from being rhythmically disorganized at the foot level.

Finally, it is illuminating to look at the frequencies of different metra. Table 4.26 shows the counts and percentages of different patterns in metron 1 and 2. In both metra the most common patterns are HHLLH and HLLHH, which together account for more than half of all metra types ( $54.55 \%$ ); different combinations of HH and LLH account for most of the rest ( $43.88 \%$ ). The fact that HHLLH and its exact inverse HLLHH are almost equally frequent is indicative of the rhythmic ambiguity that is sometimes associated with the anapestic rhythm.

### 4.4.2 Metrical structure

We now return to the question posed at the start: does the Greek anapestic dimeter have any underlying metrical structure? Recall first that the meter can be analyzed as having eight bimoraic (H or LL) metrical positions, which, in turn, have been traditionally grouped into four tetramoraic feet. This gives the anapests their unmistakable rhythmic straightforwardness. If the only requirement, however, were that feet have
four moras, we should not only observe the legal feet HH, LLH, HLL (and the rare LLLL), but also LHL. Why is LHL disallowed? On a MP-based analysis, the answer is obvious: LHL cannot be constructed from bimoraic metrical positions, unless the medial H is split between two MPs. But this raises the question why such splitting is banned-or, in other words, why must MPs be initiated with a syllable? A natural rhythmic explanation seems to be that MPs in anapests correspond to strong metrical beats; the banned LHL would make for the kind of syncopated rhythm where the last mora of the H is carried over to the strong MP. Visualizing using grids, the banned configuration is this:

| (21) | x |
| :---: | :---: |
|  | x X |
|  | 1/ |
|  | *H |

On such an analysis, there is then at least one level of periodic metric alternation in the anapests. The idea that MPs are equivalent to strong beats would also explain why H is the most common syllable in all MPs: strong positions attract H syllables (§3.4.2). The full grid for anapestic dimeters, with brackets for the two metra, would look as follows:


More disputable, and perhaps of more interest in light of the recent debate about this meter, is whether anapests have any additional levels of metrical prominence. If the traditional view of the meter as rising is correct, it would translate to the following grid structure:


That is, every other strong position would be additionally superstrong, drawing $H$ syllables more stringently than strong positions. Preliminary evidence for such a structure was given in §4.4.1 above: H syllables are indeed generally more frequent in even (i.e., superstrong) positions than odd (strong) positions. The following Maxent models test these ideas more rigorously.

### 4.4.3 Constraints

### 4.4.3.1 Pattern constraints

All five durational mapping constraints defined in §3.4.1 function as pattern contraints in the anapestic dimeter: *Empty, *Float, *Stretch, *Squeeze, and *Crowd. In addition, LONG $\Rightarrow$ STRONG is inviolable, banning syncopation. Using these constraints and the grid shown in (23), there are 128 possible line types, 34 of which are found in my dataset.

### 4.4.3.2 Preference constraints

To test the hypothesis that the anapestic dimeter has two prominence levels as shown in (23), the model will include Strong $\Rightarrow$ Long and Superstrong $\Rightarrow$ Long, which are penalized whenever a L is mapped to the corresponding grid columns. In addition, the model should be able to explain why LL is almost completely avoided metron-finally (more so than in the other superstrong positions). For the purposes of this analysis, we can formalize this preference by postulating an additional level of prominence in the metron-final beats. I will call this level "hyperstrong" (see §3.4.2) and include the constraint Hyperstrong $\Rightarrow$ Long, which penalizes L mapped to metron-final positions. The augmented grid and the violation patterns are visualized below:


Furthermore, as Figure 4.23 and Figure 4.25 show, LLH is more common in the second and fourth feet than elsewhere. This could be interpreted as a final strictness effect: assuming that LLH is the prototypical anapestic rhythm (see $\S 4.4 .8$ below), it is natural for the meter to revert to it before caesuras and line breaks. To express this preference, I will again make use of the hyperstrong level and implement the constraint Rise to hyperstrong, which says that "hyperstrong positions must be preceded by L" (see §3.4.4 for discussion).

The meter also clearly disprefers long sequences of L syllables. In my dataset, LLLL is banned both as a foot and as the sequence that would emerge if HLL was

| Constraint | Weight | AIC $_{\mathrm{c}} \Delta$ | Evidence ratio |
| :--- | ---: | ---: | ---: |
| HYPERSTRONG $\Rightarrow$ LONG | 2.79 | 426.53 | $>10000$ |
| *LLL | 2.76 | 1884.33 | $>10000$ |
| RISE TO HYPERSTRONG | 0.60 | 63.33 | $>10000$ |
| StRONG $\Rightarrow$ LONG | 0.47 | 40.68 | $>10000$ |
| *HHH | 0.21 | 18.85 | $>10000$ |
| SUPERSTRONG $\Rightarrow$ LONG | -0.55 | 52.38 | $>10000$ |

Table 4.27: Constraint weights for anapestic dimeters: simple model
followed by LLH (which is unattested). It can be assumed (with Schuh 2014) that poets avoid long stretches of Ls because of rhythmic reasons - too many Ls would disrupt the perception of a rhythmic pulse. The relevant constraint is *LLL ("Incur a violation for every ...LLL..."), which was introduced and discussed in §3.4.4. Last, I will include *HHH ("Incur a violation for every ...HHH..."), which models the observation that long unmodulated sequences of H are not as common as more variable ones (see Table 4.26).

### 4.4.4 A simple model

Table 4.27 shows the six preference constraints' weights obtained in a simple model of the dataset. $\mathrm{AIC}_{\mathrm{c}}$ model comparisons give strong support for all constraints; and judging by the weights, the most important characteristics are that metra end in H (Hyperstrong $\Rightarrow$ Long) and that long stretches of L are avoided (*LLL). A scattergram of the results (Figure 4.28) shows that the model also achieves a good fit to the data $\left(R_{\text {adj }}^{2}=0.96\right)$.

The results support the idea that metrical positions in the anapestic dimeter are equal to strong positions in the grid, as the small but positive weight for Strong $\Rightarrow$ Long ( 0.47 ) indicates. Alarmingly, however, a non-negligible negative weight was obtained for Superstrong $\Rightarrow$ Long $(-0.55)$. This is a somewhat surprising result, given that the superstrong positions are generally aligned with H syllables more frequently than positions that are just strong, as we have seen. That there exists a stringency relationship between strong, superstrong, and hyperstrong positions


Figure 4.28: Scattergram for anapestic dimeters: predicted vs. observed line counts
can be illustrated by training a model using only the three prominence constraints Strong $\Rightarrow$ Long, Superstrong $\Rightarrow$ LONG, and Hyperstrong $\Rightarrow$ Long. In such a model, all constraints are positive $(0.46,0.53,2.40$, respectively, with an evidence ratio of $>10000$ in each case). But as the $\mathrm{AIC}_{\mathrm{c}}$ comparisons in Table 4.27 show, we cannot remove the other constraints without doing serious damage to the model. ${ }^{17}$ Let us then accept that Superstrong $\Rightarrow$ Long must be negative and try to explain why this happens.

The reason, as it turns out, lies in the way the constraints interact. First, recall that the second most common metron HLLHH in my dataset violates Superstrong $\Rightarrow$ LONG (see Table 4.26 above). This already gives a hint that SUPERSTRONG $\Rightarrow$ LONG cannot be a very strong constraint here-but not yet enough to reverse its sign. An examination of the constraints' effects reveals that the main culprit is *LLL, which, by practically outlawing patterns with too many consecutive Ls, enables the competition to happen between patterns where violating

[^48]Superstrong $\Rightarrow$ LONG is often preferred. For example, if a metron ends in LLH, it cannot start with HLL, since that would violate *LLL. But if a metron ends in HH (in violation of Rise to hyperstrong), the first foot can freely be any of the three legal types (HH, HLL, LLH). And, as it turns out, the most common option in that case is HLL, the foot that violates Superstrong $\Rightarrow$ Long. ${ }^{18}$ Or, consider the frequencies of the metra that do not violate Superstrong $\Rightarrow$ Long: HHLLH (616 occurrences), LLHLLH (371), LLHHH (316) and HHHH (267). A minimal pair for these patterns that does violate SUPERSTRONG $\Rightarrow$ LONG is HLLHH, ${ }^{19}$ whose frequency (569) is clearly much lower than the total number of patterns that respect SUPERSTRONG $\Rightarrow$ LONG (1570). However, in the competition between patterns that do or do not violate a single constraint, it is not the sums of frequencies that matter but their average-recall that Maxent, being maximally noncommittal to missing information (Jaynes 1957, p.620), always distributes probabilities as uniformly as possible between all candidates. Thus, because the average number of SUPERSTRONG $\Rightarrow$ LONG-respecting patterns is much lower (392.5) than HLLHH (569), Superstrong $\Rightarrow$ LONG must plunge below zero. In sum, what the Maxent analysis reveals is that though HLL is, overall, the least common shape in the 1st and 3 rd feet (about $27 \%$ on average), it is actually the shape of choice whenever it can be chosen. ${ }^{20}$

### 4.4.5 Cross-validation

Cross-validation was again used to test how well the model generalizes (10 iterations, 3 folds). The results are shown in Figure 4.29. The weights are consistent across folds, with a good average $R_{a d j}^{2}=0.907( \pm 0.019)$, suggesting that the model generalizes well.

[^49]

Figure 4.29: Boxplot for the anapestic dimeter model cross-validation

### 4.4.6 A baseline model

As in the previous analyses, we again use a 20000 -line pseudo-corpus to investigate whether the constraints express deliberate choices of the poets. Here are some example lines:
éntosthe philēi epí èra phérōn
H H L LHLLHL LH
atekmartotátēs, hōs epitéllō
LL H LLH H LLHH
dîa gunaikôn, hè pántessin
HL LHHEHHH

The generated lines were free to be any of the 108 possible types allowed by the pattern constraints (§4.4.3.1), with the additional restriction that $95 \%$ of lines were required to have a word-break in between the two metra, just like in the real corpus. Table 4.30 shows the subtracted weights (simple-baseline) and $\mathrm{AIC}_{\mathrm{c}}$ model comparison results. The main finding is that the baseline model does not rescue the analysis: SUPERSTRONG $\Rightarrow$ Long is still negative, and even the difference between the baselineprior of $\operatorname{Strong} \Rightarrow$ Long and its true value is negative, which means that though Hs are generally more common than Ls in the anapests, in the pseudo-lines they are even

| Constraint | W | Baseline W | Diff. | $\mathrm{AIC}_{\mathrm{c}} \Delta$ | Evidence ratio |
| :--- | ---: | ---: | ---: | ---: | ---: |
| HYPERSTRONG $\Rightarrow$ LONG | 2.79 | 0.82 | 1.97 | 186.33 | $>10000$ |
| *LLL | 2.76 | 0.41 | 2.36 | 520.04 | $>10000$ |
| RISE TO HYPERSTRONG | 0.60 | -0.15 | 0.75 | 99.91 | $>10000$ |
| STRONG $\Rightarrow$ LONG | 0.47 | 0.85 | -0.38 | 27.29 | $>10000$ |
| *HHH | 0.21 | 0.09 | 0.12 | 4.11 | 7.80 |
| SUPERSTRONG $\Rightarrow$ LONG | -0.55 | 0.10 | -0.65 | 72.18 | $>10000$ |

Table 4.30: Constraint weights for anapestic dimeters: baseline vs. simple ( $\mathrm{AIC}_{\mathrm{c}}$ comparison)
more common. In addition, in the light of the baseline model the constraint *LLL finds much less support (evidence ratio 7.80) than in the simple model; the other constraints retain their value.

The conclusion is inescapable: neither the simple model nor the baseline model support the metrical structure shown in (23). What the Maxent models reveal is that the apparent dipodic alternation-which the upward-shooting lines of $\S 4.4 .1$ make seem so obvious - is due to the way that *LLL and Rise to hyperstrong (and possibly the other constraints, too) interact with each other, and cannot be attributed to a twolevel prominence structure. Although the result is humbling to the traditional view, it does not support the view that the meter is "quite chaotic" (Golston and Riad 2000, p. 157) either. In particular, the high positive weights of Hyperstrong $\Rightarrow$ Long and Rise to hyperstrong in both of the models above suggest that metron-finally, the meter does maintain order over chaos.

### 4.4.7 Restrictiveness

To complete the analysis, the non-restrictiveness hypothesis was again tested by shuffling the corpus 10 times. The results allow for rejecting that hypothesis with an average $R_{a d j}^{2}=-0.187 \pm 0.248$, mean of means of weights $-0.03672( \pm 0.12561)$, and mean of standard deviations $0.42084( \pm 0.10823)$.

### 4.4.8 Notes on performance

One clue to the rhythmic character of anapests is to be found in the text of the earliest Archaic lines: they appear to be military marching songs (West 1982a, pp. 53-54). Marching, of course, implies rhythmic regularity - and it is probably no coincidence that the earliest poems are rhythmically quite monotonous, with LLH as their most common foot (ibid.). In dramas, anapests were mainly associated with the chorus and in particular its (coordinated) movement across the stage, another pointer of their rhythmic character. The Greek name of the meter is also suggestive: anápaistos means "struck back" (LSJ, s.v.), which probably refers to the end-heavy shape of the canonical anapestic foot LLH.

As was noted at the start of this section, anapestic periods typically end in a catalectic line, which has the following form:


There appears to be no reason not to think that the catalectic line follows from the principle of saliency, the universal period-final truncation preference discussed above in §1.3.6. ${ }^{21}$ It is then also probably safe to assume that in performance, there was a lengthening or a slight pause at the end of each anapestic period. Furthermore, the regularized ending of the anapestic periods ( $\ldots \backsim \sim--$ ) lends more credence to the idea that LLH is the basic anapestic rhythmic figure, despite it not being the most frequent one overall. LLH is the choice of poets metron-finally, line-finally, and period-finally, as suits the principle of final strictness.

### 4.4.9 Summary

Some recent studies have questioned the traditional characterization of anapests as rhythmically "rising", and the analysis offered here showed that the evidence for such a characterization is indeed ambiguous (at least as concerns tragic recitative anapests, which were analyzed here). A collection of anapestic dimeters was analyzed using a grid with eight strong positions, every other one of which was additionally superstrong. In addition, a hyperstrong level was added at the end of each metron. Initial inspection

[^50]of the data supported the proposed three-level grid, as the frequencies of H are clearly positively correlated with metrical prominence. Nevertheless, Superstrong $\Rightarrow$ LONG obtained a reversed-sign weight in an (otherwise sensical) Maxent model; the rising pattern of the first and third feet turned out to be better explained by the other constraints of the model, most importantly *LLL. The anti-preference for prominence alignment did not resolve itself using a model that incorporated a baseline, corroborating the finding that the dipodic rising structure of the anapests is a by-product of other constraints. Nevertheless, poets' preference for LLH metron-finally was deemed to be intentional, which is consistent with the fact that LLH is also common periodfinally before catalexis; both can be interpreted as stemming from final strictness. This finding validates the role of LLH as the basic foot in the anapestic genre - and rebuts the idea put forth by some critics that the anapests have no rhythmic regularity at the syllable level.

### 4.5 Summing up

This chapter presented analyses of four ancient Greek meters using metrical Maxent grammars. The main goal was to describe the metrical practices of selected Greek poets explicitly in terms of well-formedness conditions on assumed correspondences between periodic metrical grids and phonological representations. In the light of the analyses, trochaic tetrameters and iambic trimeters plausibly follow a hierarchical pattern of beats of different relative strengths. Although there is a statistical tendency for some weak positions to be filled with a H syllable more often than L in these meters, this was explained as a reflection of the statistical patterning of Greek, based on a novel way of incorporating a prose baseline in the Maxent models. The analyses of comic iambic trimeters and anapestic dimeters yielded more mixed results. Comic iambs are well known to be rhythmically more flexible than non-comic lines, but they too (as the present analysis demonstrated) respect rhythmic constraints to an extent, especially towards line-end. The Maxent analyses of anapestic dimeters were particularly revealing: though anapests ostensibly follow a "rising" metric pattern, the Maxent models suggested that this is partly a side effect of the avoidance of long stretches of $L$ syllables, instead of stemming from an underlying hierarchy of metrical beats. Nevertheless, the claim made by some metrists that anapests are completely chaotic does not stand up to scrutiny, as I argued.

## Chapter 5

## Syncopation in Aeolic lyric

Unlike the rhythmically straightforward verse forms discussed in the previous chapter, the diverse category of Greek lyric ${ }^{1}$ is a microcosm of metrical variation that seems to elude any sense of rhythmic periodicity. This section focuses on the so-called Aeolic tradition of Greek poetry - as represented by Sappho and Alcaeus (7th-6th c. BCE)and argues that, given certain assumptions about the provenance of this tradition, its verse forms can be plausibly analyzed as being underlyingly periodic. My starting point is the novel proposal by Kiparsky (2018) that some of the earliest Greek meters are derived from an Indo-European source by syncopation. I extend Kiparsky's proposal by discussing the kinds of revisions it would seem to require in order to assimilate Sappho and Alcaeus' poetry.

### 5.1 Preliminaries

### 5.1.1 The Indo-European iambic prototype

The turn of the 20th century marked a paradigm shift in Greek metrics: whereas most scholars (excluding Nietzsche; see §1.1) of the 19th century had tried to apply the principles of Western art music to the metrical analysis of Greek poetry (e.g., Boeckh 1811; Rossbach and Westphal 1867), the focus now turned to the quantitative patterns

[^51]themselves, and their historical origins (e.g., Wilamowitz-Moellendorff 1921; Meillet 1923). Most scholars today believe that much of early Greek versification originated in an Indo-European (IE) metrical tradition, with clear cognates especially in Vedic Sanskrit poetry (West 2007, pp. 46-51). A typical characterization of the "common Indo-European verse", as it is called, is that though it distinguished between light and heavy syllables, it only regulated them near line-endings and otherwise only determined the number of syllables per line (e.g., Gasparov 1996). Such "syllable-counting" is also characteristic of Aeolic Greek verse, which survives in the fragments of Sappho and Alcaeus (7th-6th c. BCE).

But syllable-counting, as it turns out, is a misleading-or at least inadequateterm, if understood as a principle of metrical composition (see, e.g., Ryan 2019, p. 138, and $\S 2.2 .2$ of this dissertation). The ostensible requirement that syllables have a fixed number of syllables in each line is in many cases better analyzed as a manifestation of some more elaborate rhythmic pattern. As Arnold (1905), Ryan (2014), and Kiparsky (2018) have argued, much of the "syllable-counting" Vedic verse is based on an IAMBIC METER, especially evidently near line-ends, as would be consistent with final strictness (on which see §1.3.3). Recently, Kiparsky (2018) has proposed that much of the alleged freedom of Vedic verse is due to SYncopation, that is, the optional replacement of iambs $(\checkmark-)$ with trochees $(-\cup)$ in what seems to be a kind of quantitative counterpointing against the underlying iambic flow. Syncopation has been previously proposed to exist in other IE metrical traditions, including Sanskrit and Persian (e.g., Deo 2007; Deo and Kiparsky 2011); and if these accounts are on the right track, it is a plausible hypothesis that the Greek system, too, employs syncopation. Kiparsky (2018) sets out to examine just this hypothesis and analyzes various examples of early Greek verse as deriving from syncopated iambs, focusing on the so-called Ionian tradition, which survives in the works of Archilochus, Hipponax, Homer, and others. This chapter applies the Kiparskian analysis to Sappho and Alcaeus' fragments.

As West (2007, p. 46) says, "the governing principles of prosody and versification are essentially identical in Vedic and early Greek". Both require a fixed number of syllables per line, distinguish between light and heavy syllables, and regulate line-endings more strictly than beginnings. Moreover, both systems can be analyzed as being based on eight-syllable patterns, with typically tetrasyllabic extensions, and truncations at either end of the line. The most common Vedic verse forms are an octosyllable of the form $\times \times \times \times \cup-\smile-$ with truncated heptasyllabic variants, a twelve-syllable line with most
even positions preferably realized as $H$, as well as a catalectic version of the former with eleven syllables (e.g., West 1973b; Gasparov 1996; West 2007).

All these have parallels in early Greek verse. The main difference is that the Greek versions are quantitatively more stable: for instance, the most common Aeolic pattern, called glyconic $(\times \times-\smile \smile-\smile-)$, can be understood as a semi-fixed variant of the octosyllables also seen in Vedic, and patterns such as the pherecreatean ( $\times \times-\cup \cup--$ ) and telesillean $(\times-\smile \smile-\smile-)$ as its catalectic and headless variants, respectively. Just like in Vedic, the common Greek patterns end iambically, suggesting a shared iambic basis. The twelve- and eleven-syllable Vedic lines are also paralleled in some Aeolic verse forms, such as the Sapphic and Alcaic eleven-syllables, and glyconic variants prefixed or suffixed by the iambic metron $(\times-\cup-)$ or one of its truncated forms ( $\wedge-\cup \smile$ and $\times-$ $\left.\smile_{\wedge}\right)$. The fact that these extensions, too, are iambic in character further supports the idea that they originate in a predominantly iambic IE proto-system. However, Aeolic poets also expanded the lines from within, repeating an internal choriamb $(-\smile \smile-)$ or dactyl $(-\smile \smile)$ up to three times per line. Dactylic expansion, as I will discuss, poses a challenge for Kiparsky's syncopation theory, but can be accommodated in it.

The iambic prototype that Greek inherited from the IE system also appears to have spawned the Greek iambic and trochaic meters constructed katà métron ("with measure"), where the quantitative equivalence of - with $\smile \smile$ is already evident in resolution $(->\smile \smile)$, contraction $(\smile \smile>-)$ and responsion. The iambic trimeter, for instance, is thought to have developed from the basic octosyllable by tetrasyllabic extension (or alternatively directly from the 12 -syllable pattern also manifested in Vedic), and the trochaic tetrameter catalectic from two such octosyllables put together (Gasparov 1996; Kiparsky 2018).

The origin of Greek dactylic $(-\smile \smile)$ rhythms, especially that of the dactylic hexameter, has been subject to much debate (e.g., West 1973a; Nagy 1974; Vigorita 1977; Berg 1978). All except Nagy (1974), however, seem to agree that the hexameter is best explained as a fusion of some two cola (as argued already by Bergk 1854), whose roots are in the proto-IE patterns sketched above. Kiparsky (2018) makes the same assumption but proposes a novel derivation: the fused cola that spawned the hexameter are syncopated iambic octosyllables (ibid., pp. 106-108), yielding the familiar dactylo-spondaic hexameter pattern by the following steps:
(1)


In this derivation, the optional replacement of dactyls with spondees $(-\overline{)})$ in the hexameter would have emerged following the paradigmatic change from syllabic to moraic patterning in Greek versification (e.g., West 1973a). The proposal improves on the previous derivations, as Kiparsky argues, by giving better explanations for the peculiarities of the Greek hexameter, in particular its word-break patterns and occasional metrical irregularities (Kiparsky 2018, pp. 114-121). ${ }^{2}$ The present gives additional support to the derivation by suggesting that Aeolic dactyls, too, are based on syncopated iambs.

### 5.1.2 Quantitative metathesis

If we take syncopation in quantitative meter to mean the metathesis of $\checkmark-$ and $\cup$, it is a well-known phenomenon in traditional Greek metrics. There, however, it goes by a different name: anaclasis (Wilamowitz-Moellendorff 1921). ${ }^{3}$ The durational equivalence of light-heavy and heavy-light sequences was already well known in ancient theory (Silva-Barris 2011, pp. 40-42), ${ }^{4}$ and it can also be directly observed in both internal and external responsion in Greek verse, as will be discussed in more detail below.

[^52]In music theory, however, syncopation does not refer to the reversal of some durational pattern but to the misalignment of phenomenal accents with respect to an underlying meter (e.g., Temperley 2019). In this sense, quantitative metathesis is not yet syncopation; to treat it as such, we first need to define the metric expectation that such a reversal would violate. Traditional Greek metrics, as we have seen (§1.2), tends to focus on the classification of syllabic lengths in terms of series of metrical positions or elements (Battezzato 2009, p. 131) and in general, "seeks to identify rhythm with meter" (Valiavitcharska 2013, p. 27). So far as metathesized and otherwise quantitatively asymmetric patterns have been subject to rhythmic interpretations in this landscape, they are commonly understood as marking a shift in time-signatures or barlengths (e.g., West 1992, p. 135) rather than evincing syncopation. ${ }^{5}$ Kiparsky (2018), by contrast, separates the rhythmic patterns (and their inversions) from the underlying meters, thereby allowing syncopation to emerge in the musical sense.

### 5.2 Syncopation in quantitative meter

Let us now define "syncopation" more precisely. According to the LerdahlJackendovian (1983) theory of rhythm, meter is conveyed to the listener by a regular matching between phenomenal prominence and prominent positions in the grid. Syllable and note onsets are more prominent than sounds carried from an earlier onset; and long or stressed sounds are more prominent than short and non-stressed ones (see $\S 2.2 .2$ ). Syncopation, then, occurs when a weak beat is aligned with a more prominent sound than a strong beat next to it (Temperley 2019).

In ternary mora-based meters, such as the Greek iambic and trochaic meters composed katà métron, one can distinguish two types of syncopation, depending on which of the two $W$ beats separating each $S$ the heavy syllable is initiated in. Simply put, a $H$ can occur either too early with respect to a S position (I will call this EARLY SYNCOPATION) or too late (LATE SYNCOPATION). These configurations are pictured below (the grey background denotes a syncopated sequence).
(2) Syncopation in moraic quantitative meter

[^53]| Early |  |  | Late |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | x |  | x |  |  |
| x | X | x | x | x | x |
| H |  | L |  | H |  |

In syllabic quantitative verse - the type that early Aeolic Greek poetry representssyllables (instead of moras) are mapped to grid positions; but prominent positions still attract prominent (that is, H) syllables. In this context, too, syncopation can be understood as a rhythmic exception that can appear either in an "early" or "late" configuration: ${ }^{6}$
(3) Syncopation in syllabic quantitative meter

| Early | Late |  |  |
| :---: | :---: | :--- | :--- |
|  | x | x |  |
| x | x | x | x |
| H | L |  | L |
|  |  | $H$ |  |

Both early and late syncopation are attested in quantitative meter, including Vedic Sanskrit (Kiparsky 2018), Classical Sanskrit (Deo 2007), as well as Persian and Arabic (Deo and Kiparsky 2011). Among these, the Vedic tradition is most relevant for the syncopation-based analysis of early Greek verse, since it is historically and formally closest to it (see §5.1.1 above). On Kiparsky's (2018) analysis, Vedic is like Greek in that H syllables can be "squeezed" into weak positions (for this concept, see §3.4), but whereas Greek allows squeezing only line- or metron-initially, in Vedic any W position can be $H$, except near line-endings. L syllables in $S$ positions, on the other hand, are generally only licensed by syncopation (ibid., pp. 87-92). To illustrate, consider this trimeter (jagat $\bar{i}$ ) line (Rigveda 1.55.2b):

[^54]|  | x |  | x |  | x |  | x |  | x |  | x |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| x | x | x | x | x | x | x | x | x | x | x | x |
| L | L | H | H | L | H | L | H | L | H | L | H |
| prá- | ti | grobh-nā- | ti | víś- | ri- | tāa | vá- | rī- | ma- | bhih |  |

"Like as the watery ocean, so doth he receive the rivers spread on all sides in their ample width." (tr. Griffith 1889)

As can be seen, the line is almost invariably iambic, except for the late-syncopated second and third syllables. (Lines as straightforwardly iambic such as this one are not very common in the Vedic corpus, however.)

According to Kiparsky (2018, pp. 101-103), syncopation is not only attested in all IE quantitative meters but uniquely in them; he does not find evidence of it in any other quantitative system. There is, of course, no a priori reason for such a general rhythmic phenomenon as syncopation to be limited to IE. And in fact it is not: West Chadic meters have it too, as documented and analyzed by Russell Schuh in a series of studies (1999, 2001, 2011, 2014). To start with early syncopation, an (unnamed) ternary mora-based meter in Hausa has the basic iambic form LHLHLHLH, with a syncopated variant LHLHHLLH. Here is an example (adapted from Schuh 2014, p. 3):

|  | x |  |  | x |  |  | x |  |  | x |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| x | x | x | x | x | x | x | x | x | x | x | x

"In the way that my life prefers" (tr. ibid.)

Another example of early syncopation in Chadic comes from a Ngizim song which follows a binary mora-sensitive meter with two levels of prominence. There, lineendings are syncopated (Schuh 2011, p. 211):

|  |  | x |  |  |  | x |  |  |  | x |  |  |  | x |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| x |  | x |  | x | x |  | x |  | x |  | x |  | x |  |
| x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x

More examples of early syncopation can be found in Hausa songs in the rajaz and kaamil meters (Schuh 2011), as well as in many Bole (another West Chadic language) songs (Schuh 2001). But Chadic also employs late syncopation, as exemplified by this rajaz line (Hayes and Schuh 2019, p. e281):

"Let's get our money and collect it" (tr. ibid.)

Finally, Chadic also combines early and late syncopations, so that three H syllables fill a sequence with just two S gridmarks. Schuh adopts the musical term hemiola to denote such configurations (e.g., 2010, p. 13). The following line is from a Ngizim song, taken from Schuh (2011, p. 214):

"I am speaking in my (native) language." (tr. ibid.)

Intriguingly, syncopation can happen purely at the textual level, without being at all apparent in the performance rhythms of singing or recitation. For instance, although the rajaz line in (7) has a late syncopation near the end of the line, the poet sings the same line with an early syncopation near the beginning, and with a binary instead of ternary rhythm (Hayes and Schuh 2019, p. e281):


For general discussion about such "burying" of text-metrical phenomena under a different musical meter, see $\S 2.1 .2$. Here it will suffice to point out that examples like (7) and (9) open up the possibility to analyze verses as syncopated without making
any claims about how they were performed. I also take syncopation in poetic (textual) meter as evidence supporting a theory of meter that conceives of meters as essentially musical structures instead of phonological ones (for this argument, see Chapter 2).

In sum, syncopation is not limited to IE languages but appears to be a more general rhythmic device in quantitative meter. ${ }^{7}$ Moreover, since syncopation is a basic feature potentially available in any hierarchically organized periodicity (e.g., Temperley 1999), it might be doubted whether its appearance in a metrical tradition is best explained as a "borrowed" or historically inherited feature rather than as a manifestation of some very general cognitive process. The evidence, indeed, somewhat weakens Kiparsky's theory, where the role of syncopation as a diagnostic of historical relationship is central (2018, p. 102). Nevertheless, it leaves untouched all the other evidence supporting the common IE verse hypothesis (see §5.1); and the widespread use of syncopation in poetic meter could also be seen as buttressing the idea that Greek might have had it, too.

### 5.2.1 Syncopation in Greek: an example

Before moving on to discuss how the Aeolic metrical system can be analyzed in terms of syncopation, let us see an illustrative example. The following line by Sappho survives as fragment $123:{ }^{8}$

## Artíōs mèn à khrūsopédīlos Aúōs

## H LH L H HLLHLH H

"Just now Dawn in her golden sandals" (tr. Powell 2019, p. 31)

The twelve-syllable pattern can be described as beginning with a trochaic sequence (HLHLH), followed by a dactyl (HLL) and a trochaic close (HLHH). If one chooses to follow the general outlook of West (1992), who equates L syllables with short and H with long durations (see esp. p. 130), the rhythmic interpretation of Sappho fr. 123 might be mapped to a mora-counting grid as follows:

[^55]$\left.\begin{array}{lllllllllllllllll}x & & & & x & & & x & & x & & & & x & & & x \\ & x & x & x & x & x & x & x & x & x & x & x & x & x & x & x & x\end{array}\right)$

This would make the rhythm aperiodic $(3+3+2+4+3+3)$ - not a theoretically impossible or ill-formed pattern (e.g., London 2012, Chapter 8), and one that many traditional metrists would probably accept (see, e.g., West's anisochronous analyses of Aeschylus' lyrics in 1992, p. 140). But there are many good reasons to consider alternatives. First, as discussed above, Sappho's meters, like their Vedic cognates, are evidently syllableinstead of mora-counting; and so, mora-based measures should probably not be used here in the first place. A syllable-based grid, however, fares no better if induced by a simple $\mathrm{H} \Rightarrow \mathrm{S}$ mapping rule:


There is a rhythmic clash between the third and fourth strong beats, which makes for an ill-formed Lerdahl-Jackendovian grid (1983, p. 69). Consider then a third possibility: Sappho's metrical forms, like their Indo-European cognates, are underlyingly periodicnot necessarily on the syllabic surface, but in a way that regiments their apparent rhythmic complexity. The hypothetical IE proto-meter, however, is iambic (§5.1.1), and this pattern has, if anything, a trochaic rhythm. Similar "phase shifts" are not uncommon elsewhere in early Greek poetry (Gasparov 1996, p. 57), and there are trochaic variants of the base meter in Vedic, too (Vigorita 1979). That the pattern has twelve syllables is also important, as it suggests the line can be interpreted as a trimeter $(4+4+4)$, or, equivalently, as a dimeter with a tetrasyllabic extension $(8+4$ or $4+8$ ). More generally, the periodic analysis of fr. 123 is warranted by the fact that meters universally tend towards simplicity, as discussed in $\S 2.2 .2$, making it a priori more plausible that Sappho's verses are periodic rather than not, for all their apparent complexity.

As it turns out, fr. 123 emerges as periodic by a simple assumption: that the 6 th and 7 th syllables (HL) are syncopated. In that case, the grid would be evenly alternating:

```
x lllllllllllllll
H L H L H H L L H L H H
```

No changes were made to the basic one-to-one syllabic mapping; the only additional assumption is that Hs can be mapped to weak gridmarks anywhere in the line, so long as a strong position next to it accommodates a L. This is a straightforward example of (possible) syncopation in Aeolic verse; the full picture, as the rest of this chapter shows, is more elaborate.

### 5.3 Analyses

The hypothetical IE proto-meter is an octosyllable, or more precisely, an eight-position pattern that normally maps to eight syllables. Assuming that the pattern is iambic (Arnold 1905; Ryan 2014; Kiparsky 2018), it would look as follows using grids: ${ }^{9}$

$$
\begin{array}{cccccccc} 
& \mathrm{X} & & \mathrm{X} & & \mathrm{X} & & \mathrm{X}  \tag{14}\\
\mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X}
\end{array}
$$

The basic Aeolic cola, which are used in Greek lyrics as both independent lines and building blocks thereof (see $\S 5.3 .2$ below), are straightforward to analyze as based on the iambic grid, as Kiparsky (2018, pp. 98-99) demonstrates. Note first that the glyconic ( $\times \times-\cup \cup-\cup-$ ), from which many other patterns can be derived by catalexis and headlessness, ends in the iambic sequence $\smile-\smile-$, an evident final strictness effect (see $\S 1.3 .3$ ). Its opposite is the "free" disyllabic beginning, or the so-called Aeolic base ( $\mathrm{x} \times \mathrm{x}$ ). But even the Aeolic base is not completely irregular, as is well known. In particular, the sequence LL is rare in Archaic poets (maximally $6 \%$ of lines, according to Silva-Barris 2011, p. 108) and later banned (West 1982a, p. 30). This is explained by the iambic hypothesis: LL cannot be mapped to the first foot, because syncopation is only licensed if the number of moras is preserved. To this I would add that the move from the avoidance of LL to its complete ban in later poetry is readily explained by the historical shift from syllable to mora-counting in Greek versification (West 1973a). In syllabic meters, a foot realized as LL only violates a prominence mapping constraint; but in mora-counting meters, it incurs violations of both a prominence

[^56]mapping constraint and a durational mapping constraint (i.e., since an iambic foot has three moras and LL only two), and so must be worse.

On the iambic interpretation, the realization of the Aeolic base as HH is explainable as line-initial "squeezing", as in my analysis of trochaic tetrameter in $\S 4.1$ and iambic trimeter in $\S 4.2$ (see also §3.4.1). The same phenomenon is seen in the Hausa rajaz meter which is likewise underlyingly iambic, employs syncopation, and allows HH line-initially (Hayes and Schuh 2019). Finally, the Aeolic base can also have HL (a syncopated iamb), LH, and later also LLL, which has the required three moras and could be interpreted as a resolved iamb or trochee in a mora-counting system. ${ }^{10} \mathrm{~A}$ challenge for the iambic interpretation of the Aeolic base is that LH is on average only its third most common variant (after HL and HH) (Maas 1962, p. 25). But just like the apparent "preference" for squeezing in some anceps positions of the iambic meters katà métron (as analyzed in Chapter 4), this could be due to the lexicon and grammar of Greek instead of a true metrical choice of the poets - a hypothesis whose investigation I leave for another occasion.

Thus, the glyconic (abbreviated $g l$ ) can be interpreted as a syncopated iambic dimeter as follows:

$$
\begin{align*}
& \begin{array}{llll}
\mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x}
\end{array}  \tag{15}\\
& \mathrm{x} x \mathrm{x} \mathrm{x} \mathrm{x} \mathrm{x} \mathrm{x} \mathrm{x} \\
& \times \times-\cup \smile-\smile-g l
\end{align*}
$$

That is, the Aeolic base is followed by a syncopated iamb (i.e., the $-\cup$ above with a shaded background) and then the two regular iambic feet. The other Aeolic patterns, too (as listed by West 1982a, pp. 30-31) can be analyzed as underlyingly iambic, by adding edge truncation and "hypermetricality" (i.e., edge extension). These variants are given in (16) below.

[^57]

Under the iambic analysis, as can be seen, the syncopations generally occur in the first halves of lines, which makes sense in the light of final strictness. The ionic dimeter and its anaclastic variant (2io", a.k.a. anacreontic) stand out, however, by being the only ones employing "late" syncopation, and 2io" is especially conspicuous in having six of its eight syllables in syncopation. The next section argues for an alternative analysis of the ionics which resolves these problems.

### 5.3.1 Ionics: an alternative analysis

Interestingly, ancient theory holds that choriambs ( $-\smile \smile-$ ) and iambs ( $\smile-\cup-)$ agree with each other rhythmically, and that ionics ( $\smile--)$ agree with trochaics ( $-\cup-\cup$ ) (Consbruch 1906, p. 257; van Ophuijsen 1987, p. 23). ${ }^{11}$ The association of choriambs with iambs is clearly consistent with Kiparsky's syncopation theory and lends credence to his iambic analysis of the Aeolic variants, most of which have a choriamb after the

[^58]Aeolic basis. However, the ancient ionic-trochaic affiliation can be taken as a starting point for an alternative analysis of the two ionics 2 io and $2 i o^{\circ}$.

First, note that $2 i o^{*}(\checkmark \cup-\smile-\smile--)$ is almost equal to the first anaclastic hipponactean $(-\smile \smile-\smile-\smile--)$, the only difference being that the former lacks the - at the start. Assuming that syncopation and headlessness can be combined, we can interpret the anacreontic as a headless anaclastic hipponactean, or ${ }_{\wedge}{ }^{*} h i$. Using grids, this would look as follows:


In this mapping, the anacreontic is rhythmically trochaic (as it starts in a strong grid position), just as ancient theory maintains (see also Gasparov 1996, p. 61). Note that the line-initial $\smile$ is still interpreted to be in syncopation; its mapping to a strong position is licensed by the initial -, which, however, has been eliminated by truncation. Compare the above analysis of the anacreontic with Kiparsky's (2018, p. 101):


Arguably, the alternative analysis is preferable in that it obviates the dubious string of late syncopations, and, as noted above, is more in line with ancient testimony. It may also be relevant that in the poetry of Sappho and Alcaeus, ionics are never used in responsion with the other glyconic-family patterns (Voigt 1971, pp. 15-26).

As for the non-anaclastic version of the ionic dimeter $(\smile \smile--\smile \smile--)$, it too can be analyzed as trochaic, yielding a mapping with early syncopations in the first and third feet, and initial truncation: ${ }^{12}$

[^59]```
cllllllllll
    \smile\iota-- \smile \smile- - 2io
```

External responsion in actual Greek poetry gives some support for these proposed analyses. The best example is Anacreon's fragment 346 Page, a three-line stanza famous for its "dovetailed" verses (West 1982a, p. 58). Dovetailing, a term invented by Maas (1962, p. 44), refers to the straddling of colon boundaries by having verses end a syllable later than expected. In this case, dovetailing turns hipponacteans into ionics just the way the ionics were analyzed above. Namely, "hi becomes $2 i o$ " by initial truncation, and both respond with what appears to be a 2io with a final extension (--):


West (1982a, p. 58) comments that due to dovetailing the second and third lines of the stanza have "all the appearance of ionic". In the light of the present analysis, we might say that they are ionics-which themselves are here analyzed as alternative realizations of the same iambic grid that " $h i$ is based on. For more examples of dovetailed ionics, see Tortorelli (2004, p. 376) and Willink (2010, pp. 97-98).

As Cole (1988) highlights, dovetailing is part of a larger problem in the colometry of Greek verse: it is sometimes hard to define where the colon boundaries actually are. The relationship between different types of patterns was discussed by ancient theorists in terms of epiploké or "interweaving" (Consbruch 1906, p. 257-261). As Dale (1968, p. 41) says, epiploké simply means that different meters can be marked off from the same infinite series, such as iambs and trochees from $\ldots \times-\cup-\times \ldots$ (see also Gentili and Lomiento 2003, 2009, for discussion). In a metrical grid-based analysis, dovetailing comes out naturally as a consequence of the notion that "[a] metrical pattern can begin anywhere and end anywhere, like wallpaper." (Lerdahl and Jackendoff 1983, p. 28).

### 5.3.2 From theory to actual verse

The general plausibility of the syncopation theory depends on how well it works with actual Greek verse, rather than just being applicable to its building blocks-like the Aeolic cola-in isolation. To quote Schuh (2011) (who criticizes previous generative analyses of Arabic poetry), the risk is that one gets "side-tracked into analyzing the traditional [...] descriptive system, not the poetry itself" (original emphasis, p. 204). The cola, metra, and other ingredients that traditionalist metrists use constitute just such a synchronic descriptive system (e.g., Nagy 1992). Kiparsky's theory, by contrast, intends to be explanatory; but in order to succeed, it needs to be able to handle the syntagmatic structures of Greek lyric, where the basic patterns appear in all kinds of different combinations.

Kiparsky does, of course, discuss examples of Greek verse: he offers syncopationbased analyses of several poems by Archilochus (7th c. BCE) and Anacreon (6th-5th c. BCE), one by Hipponax ( 6 th c. BCE) and Stesichorus (7th-6th c. BCE); and he analyzes the so-called Nestor's cup (8th c. BCE) and a number of Homeric hexameters. All of these are associated with what is called the Ionian tradition of Greek lyric (West 1982a, p. 35), except the sole Stesichorus example which belongs to the Doric tradition. Although some of the earliest surviving poetic texts from Greece are Ionic in origin, it is the Aeolic tradition, with its isosyllabism and free Aeolic base, that is closest to the Indo-European roots of Greek verse (e.g., West 1973a). Kiparsky analyzes the Aeolic cola as syncopated but does not offer any analyses of Sappho's or Alcaeus' verse, where the cola are actually put to use.

In particular, the theory should be able to account for the so-called composite patterns, which have been traditionally analyzed as comprising multiple Aeolic building blocks in different line-internal combinations. For example, Voigt (1971, p. 128) analyzes the Sappho fragment 123 quoted in $(10)$ as consisting of a cretic $(-\cup-)+$ hipponactean $(\times \times-\cup \smile-\smile-)$. In addition, Greek poets expanded the patterns from within, repeating the internal sequence $-\smile \smile-$ or $-\smile \smile$ up to three times per line ("choriambic" and "dactylic" expansion, respectively). According to West (1973a, p. 185), both internal expansion and the compositing of patterns must be very early
developments in Greek versification (approximately first half of the second millennium $\mathrm{BCE}),{ }^{13}$ and indeed, as pointed out above (§5.1), both have parallels in Vedic.

It might be objected, however, that by the time Sappho and Alcaeus wrote their composites and expansions of the Aeolic cola, the sub-patterns (such as the glyconic) were conceivably no longer syncopated in the musical sense but were retained as conventionalized, by now arbitrary rhythmic figures. Like the hexameter, which must have ultimately stabilized to a straight non-syncopated meter, the Aeolic patterns indeed appear to have in some sense become "independent meters in their own right" (Kiparsky 2018, p. 98). But Kiparsky also emphasizes that his "derivations" are not meant to be understood as historical changes from one pattern to another, but as "alternative realizations of the underlying iambic pattern represented by abstract prominence relations" (ibid.). Thus, for example, in his treatment of patterns that mix dactyls with iambs in responsion (e.g., in Archilochus and Hipponax), Kiparsky says that poets must have "felt a rhythmic compatibility" (ibid., p. 111) between them. So, though the theory employs syncopation in part as a historical process that can spawn new non-syncopated meters, it also holds that syncopation is an active compositional principle in the poets' metrical grammars. It then seems to make sense to treat the Aeolic composites and expansions as explananda for the theory.

### 5.3.3 External responsion

Quantitative metathesis in external responsion lends some initial support for the syncopation theory of Greek lyric. From Archaic poetry, however, only a few examples have survived (that is, if one leaves out the Aeolic base, where metathesis is the norm). Sappho uses it sporadically (West 1982a, p. 31): fragment 95 appears to alternate regular glyconics with " $g l$ and $g l "$ (one line each), fragment 96 has one $g l "$ alongside regular glyconics, and fragment 141 has " $h i$ and $h i$ " (one line each) mixed with regular hipponacteans. To illustrate, here are the quantitative patterns of two stanzas from Sappho's fragment 96 (1l. 6-11): ${ }^{14}$

[^60]\[

\left.$$
\begin{array}{lllllllllll}
\mathrm{x} & \mathrm{x} & & \mathrm{x} & \mathrm{x} & & \mathrm{x} & \mathrm{x}  \tag{21}\\
\mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x}
\end{array}
$$\right]
\]

Once we turn to Anacreon (6th-5th c. BCE), more evidence comes up. To give just a few examples, in fragment 2 Gentili $g l^{\prime \prime}$ responds with $g l$; in fr. 4-6 and $82 i a$ with $g l$; and fr. 19-38 alternate regular ionics with anaclastic ones. Anacreon also makes the Aeolic cola respond with dactylic patterns. In Pindar (6th-5th c. BCE) and Corinna (dating uncertain) " $g l$ and $g l "$ respond (Maas 1962, p. 26). Iambs and choriambs also respond in Alcman (7th c. BCE) fr. 59 Page, Simonides (both 6th-5th c. BCE) fr. 545 Page, as well as sporadically in tragedy and comedy (Korzeniewski 1968, p. 102, Itsumi 1982, West 1982a, p. 68, 105). This is not an exhaustive list of metathesis in responsion; but it suffices to show that $\smile-$ and $-\cup$ are clearly rhythmically compatible in Greek versification.

### 5.3.4 Internal expansion

Choriambically expanded cola present no problem for the syncopation theory, because the choriambic metron ( $-\smile \smile-$ ) can be easily interpreted as a syncopated iamb, and because the two were affiliated in ancient theory (see §5.3.1 above). Tetrasyllabic internal expansion is also attested in Vedic (West 2007, p. 49). To illustrate, here is $g l^{2 c}$ (i.e., a glyconic with a double choriambic expansion) mapped to an iambic tetrameter grid:


Variants with single and triple choriambic expansions can be analyzed iambically just as straightforwardly, both of which appear in Sappho and Alcaeus in different guises (e.g., gll ${ }^{1-3 c}, p h^{2 c}, h a g^{1-2 c}$; see West 1982a, p. 32).

Dactylic expansion, on the other hand, is more problematic for the theory, because a dactyl does not in itself constitute an iambic metron. One of the clearest examples of dactylic expansion is Sappho's fr. 94, a stanza with two $g l$ lines followed by $g l^{d}$. Mapped to an iambic trimeter grid, the patterns look as follows:

|  | x |  | x |  | x |  | x |  | x |  | x |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| x | x | x | x | x | x | x | x | x | x | x | x |  |
| $\times$ | $\times$ | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - |  |  |  |  | $g l$ |
| $\times$ | $\times$ | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - |  |  |  |  | $g l$ |
| $\times$ | $\times$ | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - |  | $g l^{d}$ |

The mapping of the third line, if correct, is unusual: though the pattern ends in what looks like an iambic sequence $(\smile-\cup-)$, the four final syllables must be syncopated in order for them to be aligned with the grid, seriously violating final strictness. Note that on the assumption that the line is a trimeter, it is also catalectic.

Line-final late syncopation with catalexis also appears in Kiparsky's (2018, p. 108) iambic analysis of the hemiepes $(-\cup \smile-\succ \smile-, D)$. Using grids, it is mapped as follows:


If Kiparsky's analysis of $D$ is correct (and he gives data to support it; see ibid., p. 107,111 ), the string of late syncopations before catalexis in the present derivation of $g l^{d}$ may be nothing to worry about. ${ }^{15}$ Still, there is an alternative interpretation of $g l^{d}$ worth considering-though it will mark a departure from Kiparsky's original proposal. Suppose that $g l^{d}$ is not underlyingly iambic, but maps to a trochaic meter instead. In other words, we start by aligning the first $\times$ of the Aeolic base with a strong beat, and proceed rightwards from there. The following mapping would emerge:

[^61]```
l lllllllllllllll
× × - \smile \smile-\smile \smile- \smile- gld
```

This would regularize the iambic ending, removing the (perhaps dubious) linefinal syncopations of (23) above. The idea that some glyconic-family patterns are underlyingly trochaic instead of iambic is not entirely implausible in the light of IndoEuropean metrics: Vedic, too, has genuinely trochaic meters (i.e., trochaics not derived from iambs by headlessness). The so-called trochaic Gāyatrī (Arnold 1905, p. 165; Vigorita 1979) is an octosyllable having the schema $\times \times \times \times \mid-\cup-\cup$, which is similar to a normal Vedic dimeter but has a trochaic clausula. Nagy (1974, pp. 170-171) suggests that the trochaic Gāyatrı̄ and the Greek trochaics share a common IE origin (see also Oldenberg 2005, p. 24).

However, there is another anomaly in the trochaic mapping of $g l^{d}$, as shown in (25). As can be noticed, the seventh syllable (i.e., the last $\smile$ with a shaded background) is not "licensed" to be realized as L, because also the position that follows it has an L ; there is a mora gone missing. This would violate the basic assumption of Kiparsky's theory that syncopation cannot change the mora count of lines (2018, p. 122). But again, we find a parallel in Vedic, where similarly unlicensed mappings of LL to SW or WS sequences are common in certain verse forms. For instance, the Vedic jagatī-line commonly takes the following form (Vigorita 1976, p. 37):

```
x\times\times\times\times|
```

Just like the trochaically mapped $g l^{d}$, this jagatı pattern has an L syllable in what can only be a strong position (judging by the straightforward iambic ending), namely, the first $\smile$ after the caesura (see also Gasparov 1996, p. 51; Gunkel and Ryan 2011). In the next section, I will suggest that some of Sappho's and Alcaeus' composites give additional support to the idea that early Greek verse sometimes has unlicensed Ls in strong positions.

If the trochaic interpretation of ${g l^{d}}^{\text {is correct, the stanza by Sappho we have been }}$ considering would be mapped as follows:


According to this analysis, the first two $g l$ are iambic and the third one $\left(g l^{d}\right)$ trochaic, which is less than ideal. But responsion of iambics and trochaics is not unheard of in Greek versification. For instance, in Archilochus' fragment 322, 2ia responds with ^2ia (Gerber 1999, p. 280). Additional, if weak, support for the proposed analysis can be found in the word-break patterns of Sappho's fr. 94, as given by Voigt (1971, p. 15). In the first two verses there is a common word-break after the third syllable, but in the third line after the second. The proposed mapping would align these breaks: all occur after the third gridmark.

Turning to the doubly expanded glyconic $\left(g l^{2 d}\right)$, it can be mapped to an iambic grid as follows:


Thus analyzed, the pattern has a "normal" iambic Aeolic basis as well as a regular iambic ending, two syncopations as well as one unlicensed $\smile$ (position 10). It is also catalectic by two syllables, missing an entire foot at the end. Rhythmically, the pattern resembles the fourteen-syllable $g l^{2 c}$ (see (22) above), which starts with the same tetrasyllabic sequence and likewise closes iambically. It is interesting to note that in the Hellenistic metrical organization of Sappho's poems (Battezzato 2018), the second book was written entirely in $g l^{2 d}$ and the third one in $g l^{2 c}$. Thus, the rhythmic likeness of the two patterns that emerges on the present analysis is paralleled by their ancient organization.

As for the longest variant in this category, in Sappho and Alcaeus only the catalectic variant of $g l^{3 d}$ is attested-that is, $\mathrm{ph}^{3 d}$ (West 1982a, p. 32). We can again consider both iambic and trochaic mappings:


Here the choice is less than obvious：the iambic mapping is preferable in that it only has one unlicensed $L$（10th syllable）as opposed to the two of the trochaic mapping（7th and 13 th syllables）；on the other hand，the former has one additional syncopation，one of which is near line－end．Of course，it is also possible that neither mapping is right． $p h^{3 d}$ is only used stichically by the Aeolic poets（see Voigt 1971，pp．15－26）and so there is no direct evidence（i．e．，from external responsion）in favor of either．In the following section，however，I analyze a stanza in Sappho in which an evidently iambic composite responds with $6 d a_{\wedge}$ ，a pattern that resembles $p h^{3 d}$ ；see（51）below．That analysis gives indirect support to the iambic mapping of $p h^{3 d}$ ，as shown above．

In sum，to explain the dactylically expanded Aeolic cola the syncopation theory appears to require the following revisions：1）the possibility that some Aeolic patterns have line－medial $L$ syllables mapped to strong positions without being licensed to do so by syncopation（similarly to some forms of Vedic meter），and 2）either accept additional cases of late syncopation close to the ends of verses，or allow for the possibility that sometimes the Aeolic basis started in a strong instead of a weak beat．The analyses given in the next section offer more evidence for the hypothesis that $\times \times$ is mapped trochaically in some dactylic patterns．

## 5．3．5 Composites

## 5．3．5．1 Alcaeus

Let us now examine the Aeolic composites which survive in the fragments of Alcaeus and Sappho．Starting with Alcaeus＇stichic forms，Voigt（1971，p．22）lists eight different patterns，three of which are shown below（with Voigt＇s composite analyses on the right）：

$$
\begin{align*}
& \times-\cup-\times--\cup \cup-\cup-\quad i a g l  \tag{30}\\
& \times--\smile \smile-\smile-\smile-\smile-g l i a \\
& \times ー \smile \cup-\cup-\cup-\cup-\quad \text { ィ } l i a
\end{align*}
$$

It is easy to see that all three map straightforwardly to an iambic grid．Assuming that $g l$ is underlyingly an iambic dimeter，the $i a g l$ and $g l i a$ are iambic trimeters（since
$i a$ adds a third metron), and $\wedge_{\wedge} g l i a$ is a headless iambic trimeter. The patterns (all of which come from different poems) are aligned with an iambic grid as follows:

|  | x |  | x |  | x |  | x |  | x |  | x |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| x | x | x | x | x | x | x | x | x | x | x | x |  |
| $\times$ | - | $\checkmark$ | - | $\times$ | - | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - | ia gl |
| $\times$ | - | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - | $\checkmark$ | - | $\checkmark$ | - | gl ia |
|  | $\times$ | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - | $\checkmark$ | - | $\checkmark$ | - | ^gl ia |

The following is a fourth stichic composite in Alcaeus:

$$
\begin{equation*}
\smile-\cup-\times-\cup \smile-\cup--\quad i a \wedge_{\wedge} h i \tag{32}
\end{equation*}
$$

Hephaestion (2nd c. CE) analyzes this pattern as a trimeter "mixing in an opposition" (kat' antipátheian mikseōs; van Ophuijsen 1987, p. 134). The word "opposition" here refers to the observation that the pattern contains both iambic and trochaic metra: it starts with an iambic metron ( $\smile-\smile-\times \ldots$ ) but ends trochaically ( $\ldots-\cup-$ $-)$. As with the dactylically expanded glyconics (§5.3.4), we can compare iambic and trochaic mappings of the entire pattern:


The iambic mapping would create a string of line-final late syncopations, but it has fewer syncopations in total than the trochaic alternative ( 2 vs. 3 ). The former also has the medial anceps ( $x$ ) mapped to a weak position, which would make sense, as the anceps is straddled between two H syllables. On the other hand, the iambic mapping causes ${ }_{\wedge} h i$ to be aligned with the grid differently from that given in (16) above. Namely, in (16) $\lambda i$ was interpreted as a headless + hypermetrical glyconic, which starts in a strong position. The trochaic mapping of (33) matches that alignment; the iambic does not (it has the ${ }_{\wedge} h i$ starting in a weak position). In sum, the periodic interpretation of this pattern remains ambiguous.

Fifth, Alcaeus uses a pattern analyzed by Voigt as a glyconic composited with an iambic metron:

$$
\begin{equation*}
---\cup \cup-\cup \cup-\cup-\cup-\cup-g l^{d} i a \tag{34}
\end{equation*}
$$

Voigt interprets the pattern as starting with a $g l^{d}$; this would mean that the initial -- are actually $\times \times$ realized as HH. The composite is particularly interesting in that its long iambic ending gives a clue about the rhythmic interpretation of $g l^{d}$. Recall from §5.3.4 that $g l^{d}$ could be mapped as either underlyingly iambic (23) or trochaic (25). If Voigt's composite analysis is right, mapping the pattern trochaically clearly supports the trochaic analysis of $\mathrm{gl}^{d}$ :


On the iambic interpretation of $g l^{d}$, the entire line-final iambic sequence $\checkmark-\smile-\smile$ $-\cup-$ is late-syncopated, as (35) shows. The trochaic mapping, in which the Aeolic base starts in a strong grid position, is then clearly superior in this case.

The remaining three stichic Alcaic composites listed by Voigt are these:


The first two (2gl ia and gl hi) are based on variants of the glyconic with no lineinternal catalexis or hypermetricality-refer to (16) above - and so present no challenge for an iambic analysis. The third pattern ( $p h g l$ ), however, is again ambiguous, because the pherecratean $(p h)$ is a catalectic glyconic $\left(g l_{\wedge}\right)$, which leaves a gap between the two cola ( $g l_{\wedge} g l$ ). But there is no need to follow Voigt's colometric analysis blindly. As can be seen, the pattern that Voigt analyzes as $p h g l$ starts with $\cup \cup$, which would be an unusual variant of the Aeolic basis (see the start of §5.3), though admittedly only one line survives (fr. 322). The two Aeolic cola that regularly start with LL are the two ionics $\smile \cup--\cup \smile--$ and $\smile \smile-\smile-\cup--$, which I analyzed above (§5.3.1) as starting in a strong position. Suppose now that this pattern, too, is trochaic, and a relatively simple mapping emerges:

$$
\begin{align*}
& \smile \smile-\cup \smile--\cup--\cup \smile-\smile-\text { (trochaic) } \tag{37}
\end{align*}
$$

In this mapping there are only two syncopations (early and late), and a regular iambic ending. An iambic mapping would be much less straightforward, with a sequence of late syncopations:

$$
\begin{align*}
& \smile \smile-\jmath \smile--\cup--\jmath \smile-\smile-\quad \text { (iambic) } \tag{38}
\end{align*}
$$

Next, let us turn to Alcaeus' strophic compositions. Most of them employ choriambic expansions, iambics + glyconics, pure glyconics and ionics (see Voigt 1971, pp. 20-22). All of them can be analyzed easily using binary grids - except for two: the "Alcaic" and "Sapphic" stanzas. The Alcaic stanza is as follows:

| $x-v-x-u v-u-$ | $i a_{\wedge} g l$ |
| :---: | :---: |
| $x-\cup-x-\cup v-\cup-$ | $i a_{\wedge} g l$ |
| $\times$ | $2 i a, ~ h i^{\text {d }}$ |

To start with the first pattern of the stanza (lines 1-2), there is again an apparent rhythmic reversal in the middle, because the straight $i a$ is followed by the headless glyconic ( $\wedge g l$ ). Note that the pattern is the same as $i a{ }_{\wedge} h i$ (see (33)), but without the hypermetrical final syllable. This then once again brings up the problem of choosing between a trochaic and iambic grid alignment-which of the following, if either, is correct?


The third line of the stanza (2ia ${ }_{\wedge} h i^{d}$ ) gives a clue. Its most straightforward mapping, as it appears, is iambic: first comes a straight iambic sequence that ends in an anceps mapped to a weak position $(x-\smile-x-\cup-x)$. Ancient metrists split the line here in two, but syntax and occasional words crossing the caesura suggest that
the line is a complete verse (e.g., Battezzato 2009, p. 126; West 1982a, p. 33). Thus, if the line-initial sequence $(x-\cup-x-\cup-x)$ is mapped iambically, it ends in a weak position, making the rest of the pattern $(-\cup \smile-\cup \smile-\cup--)$ start in a strong position. Thus interpreted, the iambic mapping would be straightforward:

As can be seen, this mapping is not just straightforwardly iambic (save for the three-syllable $\smile-\smile$ in the middle), but most importantly, it makes the pattern end in a non-syncopated sequence $(\ldots \smile-\cup--)$ making the stanza as a whole respect final strictness. In addition, the iambic mapping would support the iambic interpretation of the first two lines of the stanza ( $i a \wedge g l$ ) as well, as it renders the entire stanza iambic. Finally, note that in the above mapping, $\wedge i^{d}$ is aligned in a way that is compatible with the trochaic interpretation of the dactylically expanded glyconic, since $\wedge_{\wedge} h i^{d}={ }_{\wedge} g l^{d}-\quad$. The here proposed analysis of $2 i a{ }_{\wedge} h i^{d}$ thus corroborates the trochaic interpretation of the dactylically expanded glyconics (see §5.3.4 and (35) above).

Finally, Alcaeus uses the Sapphic stanza, which I analyze below along with Sappho's other strophic compositions.

### 5.3.5.2 Sappho

Voigt (1971, pp. 15-20) lists the following stichic forms found in Sappho's fragments: ${ }^{16}$

| $-\cup---\cup \cup-\cup \cup-\cup--$ | cr $\wedge_{\wedge} h i^{d}$ |
| :---: | :---: |
| - - - - - - - - - | cr $h i$ |
| - - - - - - - | $2 i a_{\wedge} g l$ |
| $\times \times$ - $\quad$ - | $g l ~ b a$ |
| - - $-\cup-\cup-\cup-$ | $\wedge g l b a$ |
|  | 2ia gl ba |
| $-\cup-<\times \times-\cup \cup-\cup>$ (repeated 3 times) $\smile--$ | cr 3 gl ba |
| $\times$ - $-\cup \cup-\cup-\cup--$ | 2ia 2io. |
| - $-\cup-$ - | 3 cho ba |

[^62]Of these nine patterns, six are easy to analyze as periodic under the basic assumptions of the syncopation theory: cr hi, gl ba, 2ia gl ba, $, ~ g l ~ b a, ~ c r ~ 3 g l ~ b a$, and $3 c h o$ $b a$. This is evident because an initial $c r(-\cup-)$ continues seamlessly with an iambic pattern (as in $c r h i$ ); and a line-final $b a(\smile--)$ accepts any acatalectic iambic (or syncopated iambic) pattern its precedent (as in $g l b a,{ }_{\wedge} g l b a$, 2ia $g l b a, ~ c r ~ 3 g l b a$, and 3 cho ba). Here are the mappings:

|  | X |  | X |  | X |  | X |  | X |  | X |  | X |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |  |
|  | - | $\checkmark$ | - | $\checkmark$ | - | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - | - |  |  | cr $h i$ |
| $\times$ | $\times$ | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - | $\checkmark$ | - | - |  |  |  |  | $g l ~ b a$ |
| $\checkmark$ | - | $\checkmark$ | - | $\checkmark$ | - | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - | $\checkmark$ | - | - | 2ia gl ba |
|  | - | $\checkmark$ | - | $\times$ | $\times$ | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - | $\checkmark$ | - | - | cr 3 gl ba |
| - | $\checkmark$ | $\checkmark$ | - | - | $\checkmark$ | $\checkmark$ | - | - | $\checkmark$ | $\checkmark$ | - | $\checkmark$ | - | - | 3 cho ba |

It is interesting that most of Sappho's stichic composites are straightforwardly analyzable as periodic, based on the basic assumptions of Kiparsky's theory.

But three patterns remain: 2ia $\wedge_{\wedge} g l, c r \wedge_{\wedge} h i^{d}$, and 2ia 2io". The first of these, 2ia $\wedge g l$ is the same as that used in the Alcaic stanza (lines 1-2), and was already analyzed above in (40). cr $\wedge i^{d}$ looks, at first sight, problematic for the syncopation theory, due to its line-medial truncated position. However, under the assumption that dactylically expanded Aeolics are trochaic instead of iambic (see again $\S 5.3 .4$ and the above section on Alcaeus' verse), the line maps perfectly well. To illustrate, (44) shows both iambic and trochaic interpretations:


As can be seen, the trochaic mapping is clearly preferable here, with just one syncopation (positions 7-8) and a single unlicensed L; in the iambic version almost all positions are syncopated. Furthermore, in the trochaic mapping, the single $\times$ position translates to a weak gridmark, just as it arguably should (i.e., employing "squeezing" instead of "stretching"). Accordingly, this analysis gives further support for the trochaic mapping of $g l^{d}$ and its cognates.

The third pattern, 2ia 2io" (attested in fr. 133), combines iambics and ionics in a way that is consistent with Kiparsky's (2018, p. 101) iambic analysis of the ionics. Following that analysis, it would be mapped as follows:

$$
\begin{align*}
& \begin{array}{llllllllllllll} 
& \mathrm{X} & & \mathrm{X} & & \mathrm{X} & & \mathrm{X} & & \mathrm{X} & & \mathrm{X} & \\
\mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X} & \mathrm{X}
\end{array}  \tag{45}\\
& \times-\smile-\smile \smile-\smile-\vee-\quad \text { 2ia 2io. }
\end{align*}
$$

As with the non-composited 2 2io" $^{*}$, as given in (16), the iambic mapping creates a sequence of three late syncopations, making it somewhat doubtful. But again, we must not let the colometric analysis lead us astray. As it turns out, the pattern in question ( $\times-\cup-\smile \cup-\smile-\smile--)$ could be alternatively analyzed without using ionics at all. Looking at the list of cola in (16), we can see that it includes an anaclastic version of the hipponactean $\left(h i^{*}\right)$, which has the shape $\times \times-\smile-\smile \smile--$. Suppose that just like any other Aeolic colon, this one too could be truncated initially, yielding the pattern $\times$ $-\smile-\smile \smile--$. This, of course, is just the sequence that starts the Sappho fr. 133 we are considering here. By extending it by a $2 \operatorname{tr}(-\cup--)$, we get the full pattern. A trochaic mapping then would look good:

$$
\begin{align*}
& \begin{array}{lllllllllllll}
\mathrm{x} & & & \mathrm{x} & & \mathrm{x} & & \mathrm{x} & & \mathrm{x} & & \mathrm{x} & \\
\mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x}
\end{array}  \tag{46}\\
& \times-\smile-\smile \cup-\smile-\smile--\wedge h i{ }^{2} 2 t r
\end{align*}
$$

With just two early syncopations at the beginning of the pattern (positions 2-4), the mapping is arguably preferable to the Kiparskian mapping given in (45).

To turn to Sappho's stanzas, nine metrical forms survive (Voigt 1971, pp. 15-16). The most famous one is, of course, the Sapphic stanza, which is as follows:

$$
\begin{align*}
& -\smile-\times-\smile \smile-\smile--\quad \text { cr } h i  \tag{47}\\
& -\cup-\times-\cup \cup-\cup--\quad \text { cr } h i \\
& -\smile-\times-\cup \cup-\cup-\times \mid-\cup \smile--\quad c r{ }_{\wedge} g l \wedge p h
\end{align*}
$$

The first pattern (cr hi), as is well known, is the same as the first line of the Alcaic stanza $(i a \wedge g l)$, but with its first syllable moved to the end. It could also be described as $\wedge_{\wedge} 2 i a{ }_{\wedge} h i$, the non-headless version of which Alcaeus uses stichically; see (33) above. Hephaestion, on the other hand, analyzes the line as a trimeter with the metra in opposition (van Ophuijsen 1987, p. 130), and I will follow that analysis here (see also

West 1992, p. 149 and Silva-Barris 2011, p. 141). In the present framework, this yields the following mapping, with two late syncopations near the end:

$$
\begin{array}{llllllllllll}
\mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} &  \tag{48}\\
\mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x}
\end{array} \quad \begin{aligned}
& \text { ( } \\
& - \\
& -
\end{aligned}
$$

As for the third pattern, ancient theory (e.g., Hephaestion, ibid., p. 131) divides it into two separate lines by the caesura before the final adonean ( $-\smile \smile--)$, but just as with the third line of the Alcaic stanza (and for the same reasons), the pattern is better treated as a single verse. But arguably, its analysis as $c r \wedge g l \wedge p h$ (defended by Battezzato 2009) unnecessarily obscures its likeness to the two previous lines; the only difference really is that it has the final adonean added. Suppose then that the better decription of the third verse is in terms of cr hi ad. The two first cola (cr $h i$ ) can then be analyzed in the same way as in (48) above. The following adonean (ad) can be analyzed as a choriamb with a hypermetrical - at the end, and so, just like the choriamb itself, as underlyingly iambic. What would emerge is a relatively straightforward alignment to the alternating grid:

$$
\begin{align*}
& \begin{array}{lllllllll}
\mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x}
\end{array} \tag{49}
\end{align*}
$$

$$
\begin{aligned}
& -\smile-\times-\smile \smile-\smile---\smile \cup--c r \wedge g l \wedge p h=c r h i a d
\end{aligned}
$$

This proposal also solves a problem brought up by Silva-Barris (2011, p. 122). Namely, if the first two lines of the Sapphic stanza are interpreted as trimeters (e.g., van Ophuijsen 1987, p. 130), with 11 syllables they appear to be catalectic, as shown in (48). According to Silva-Barris, if the third line is likewise analyzed in terms of "inverse groups" (i.e., syncopation, in the present framework), that would leave an empty position between $c r h i$ and the final $a d$; but the lack of word-breaks in that position speaks against such a hypothesis. If, on the other hand, the final ad is mapped iambically, as in (49), the problem disappears, as the truncated (weak) position after cr $h i$ is filled by the first syllable of $a d$.

Sappho also used the Alcaic stanza in her compositions; and another one of her stanzas $\left(g l|g l| g l^{d}\right)$ was discussed above in (23). Of the six that remain, in Voigt's analysis four of them use pure and choriambically expanded Aeolics, as well as a simple
composite pattern ( $c r g l$ ), all of which have already been analyzed above. But one of her stanzas is an intriguing combination of dactyls and iambics (fr. 104a):
$-\cup \cup-\cup \smile-\cup \smile-\cup \smile-\cup \smile--6 d a_{\wedge}$
$\smile-\cup-\cup--\cup \cup-\cup \smile-\cup \smile--\quad 2 i a p h^{2 d}$

At first blush, the two lines appear to be rhythmically incompatible, the first one being dactylic and the second one an Aeolic composite. But as we have seen, Kiparsky's theory treats dactyls as originating in syncopation. And indeed, by mapping both lines iambically from left to right the superficially disagreeing patterns turn out to respond nearly perfectly:


In this light, the strophic responsion between $6 d a_{\wedge}$ and $2 i a p h^{2 d}$ emerges as a striking example of the rhythmic compatibility between dactyls and iambs in Aeolic poetry, a core idea of Kiparsky's proposal, and for which the present analysis thus gives additional support. Note, however, that in order for the analysis to work, the additional assumption must be again made that Aeolic meters sometimes allow unlicensed L syllables in strong positions.

The analysis given in (51) may also help to choose between the iambic and trochaic mappings of $p h^{3 d}$, which were considered in §5.3.4. If the above mapping of $6 d a_{\wedge}$ is correct, a trochaic mapping of $p h^{3 d}$ would make more sense, as illustrated below:


On this interpretation, the only difference between $6 d a_{\wedge}$ and $p h^{3 d}$ is that $p h^{3 d}$ has a trochaically mapped Aeolic basis in place of the initial dactyl of $6 \mathrm{~d} a_{\wedge}$.

There is also an obvious likeness between these patterns and the dactylic hexameter, whose iambic analysis was the main goal of Kiparsky's (2018) article (see esp. pp. 106-107). The present analysis, however, differs from Kiparsky's treatment of the
hexameter. Kiparsky argues that the hexameter originates in two syncopated iambic dimeters put together $(-\smile \smile-\smile \smile--+-\smile \smile-\smile \smile--$, or $D-D-$ ), where the $\varpi$ position then emerges only later, after the equivalence of - and $\smile \checkmark$ has been instituted in Greek versification. The differences between the above analysis of $6 d a_{\wedge}$ and Kiparsky's analysis of the hexameter are illustrated below:


It is conceivable, however, that both mappings are correct: the former characterizes the Aeolic hexameters (as suggested by the evidence given above) and the latter the Homeric hexameter (as discussed by Kiparsky). This would not be the only respect in which the Aeolic and Homeric hexameters differ: they also have distinct word-break patterns, use a different dialect, and whereas the former is strictly isosyllabic (with a few odd exceptions), the latter allows the contraction of $\smile \succ$ to - (West 1982a, p. 34). They also come from different metrical traditions (i.e., Aeolic and Ionian), which, according to West (1973a, p. 29), had already separated in second millennium BCE.

To return to Sappho's other stanzas, the last form not yet discussed survives in fragment 104: ${ }^{17}$


The first line is a catalectic-headless glyconic $\left({ }_{\wedge} g l_{\wedge}={ }_{\wedge} p h=r\right)$, but the second and third verses appear at first blush to be almost random. To start deciphering them, it may first be pointed out that both patterns start in what can be interpreted as an iambic metron with initial squeezing $(x-\cup-)$; in addition, both end in a trochaic sequence $(\checkmark--)$. Note then that both lines have 19 syllables. Taken together, these observations suggest the interpretation that the lines are catalectic iambic pentameters $(4+4+4+3)$ with occasional syncopations. These mappings would follow:

[^63]|  | X |  | X |  | X |  | X |  | X |  | X |  | X |  | X |  | X |  | X |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| $\times$ | - | $\checkmark$ | - | $\times$ | - | - | $\checkmark$ | $\times$ | - | - | $\checkmark$ | - | $\checkmark$ | - | $\checkmark$ | $\checkmark$ | - | - |  |
| $\times$ | - | $\checkmark$ | - | $\times$ | - | - | $\checkmark$ | $\times$ | - | - | $\checkmark$ | $\times$ | - | $\checkmark$ | - | $\checkmark$ | - | - |  |

So far as the general approach pursued here is valid, these mappings are unproblematic. The string of three early syncopations in the first line (positions 11-16) is paralleled by Sappho's fragment 95 (l. 9) and 96 (l. 7), which West (1982a, p. 31) analyzes as anaclastic glyconics $\left(g l^{\prime \prime}, \times \times-\cup-\cup \smile-\right)$.

### 5.4 Summing up

This chapter examined the metrical forms of the poetry of Sappho and Alcaeus from the perspective of Kiparsky's (2018) syncopation theory, according to which some of the earliest meters in Greek poetry-like their possible Indo-European cognates-employ syncopation. The main aim was to see how the theory handles the so-called composite and expanded patterns that Sappho and Alcaeus use in their stichic and strophic compositions, which Kiparsky did not cover in his article. In the light of the analyses presented here, if the theory is to accommodate these texts, it would seem to require two revisions. First, it must allow for the alignment of $L$ syllables with strong positions, even when such mappings are not licensed by an adjacent H in a weak position as per mora-preserving syncopation. Second, some dactylically expanded patterns appear to map better to an alternating grid if it is assumed that they are underlyingly trochaic instead of iambic. That the second modification must be made is evident by such composites as $c r{ }^{"} h i^{d}$ (Sappho, fr. 155), which would map as almost straight trochaics but inconceivably complex iambics. Both of these revisions-unlicensed Ls in strong positions and genuinely trochaic mappings-are paralleled in Vedic poetry, which lends plausibility to these revisions. I also suggested a new trochaic analysis of the ionic cola (2io and 2io"), based on ancient testimony and evidence from external responsion.

## Chapter 6

## Against Prosodic metrics: (Greek) meter is not phonology

The existence of metrical templates as language-external objects is a subject of debate in generative metrics. According to template-matching theory, poetic meter involves an abstract rhythmic pattern and a set of correspondence constraints regulating the arrangement of phonological material. Its main contender, Prosodic metrics, attempts to eliminate the metrical templates, arguing that recurring features that need to be stipulated in templates-in particular, binarity and eurhythmy-can be generated directly by ranked phonological constraints. This chapter argues against the Prosodic metrics approach as applied to the analysis of Greek meter, pointing out a number of conceptual and empirical shortcomings of this approach.

### 6.1 Prosodic metrics

Like most other contemporary generative approaches to meter, Prosodic metrics (henceforth PM) tries to characterize metrical well-formedness conditions in terms of constraints (Golston and Riad 1994, 1995, 1997, 2000, 2005; Golston 1998, 2021; Riad 2009, 2017). In addition, PM at least implicitly subscribes to the frequency hypothesis of Halle and Keyser (1971a), according to which the relative frequencies of different line types are inversely correlated with their metrical complexity (e.g., Golston and Riad 2000, p. 118: "the relative frequency with which each type of foot occurs is a function of how well it respects [a constraint]"). Most importantly, like a number of other generative accounts (e.g., Blumenfeld 2015; Kiparsky 2020), PM
strives to analyze meter using strictly linguistic assumptions and methods (see also $\S 2.1)$. However, it differs from most other generative theories of meter by abandoning the idea that the constraints' role is to evaluate phonological patterns against abstract rhythmic representations.

Instead, Golston and Riad (2000) argue that since metrical patterns across traditions tend to follow the same basic rhythmic principles, and because these principles also occur in ordinary phonology, many properties of metrical structures can be predicted using regular linguistic constraints that deal with rhythm (e.g., *CLASH, *Lapse; see, e.g., Kager 2007) and structural unmarkedness (e.g., FtBin "Feet are binary"). ${ }^{1}$ In other words, meters can be generated directly by grammar, removing the need to postulate an underlying metrical template external to verse. As we will see, because not every meter can respect all the relevant constraints (otherwise, they would all be the same!), in the PM view, some meters are characteristically arrhythmic. In this respect, PM probably differs from all other approaches to metrical analysis that are currently being pursued.

PM-style analyses typically emphasize that meters across languages tend to be binary in several respects. A prevalent type of stress-based verse, for example, is one with eight metrical positions, four feet, and two metra, forming a hierarchy of constituents that branch twice (see Golston 1998, p. 731, and the references therein). Taking Hayes' (1989b) idea seriously that the metrical groupings are analogous to prosodic constituents, PM proposes that the binarity of meter is nothing but phonological unmarkedness extended to all levels of the prosodic hierarchy. A well-formed metrical structure is then simply one among the set of possible structures that respects binarity constraints on prosodic structure. Such constraints include IntBin (intonational phrases should branch twice), PHBiN (phonological phrases should branch twice) and WdBin (words should branch twice). Assuming that words contain feet, an unmarked intonational phrase would look as follows:

[^64]

The phonological foot, too, branches twice in the unmarked case (respecting FtBin; Prince and Smolensky 2004): in quantity-sensitive languages it is assumed to be maximally bimoraic, and in others disyllabic. Foot binarity means that in Greek and other quantitative metrical systems, an unmarked phonological foot is either H or LL, and L or empty in the marked case. The critical point here is that a fully binary structure is what a hypothetically completely unmarked prosodic structure would look like-PM does not take such structures to be underlying templates to which lines are matched, as is the case of template-based theories.

But though structural binarity and eurhythmy are indeed typical of meters universally, exceptions are also very common. A common example is catalexis, or the truncation of a line-final syllable or sequence (see $\S 1.3 .6$ ). From the perspective of PM, any deviation from perfect rhythm incurs a violation of some rhythmic well-formedness constraint-and here comes the twist: in PM, any recurrent deviation from binarity, such as catalexis, can be LeXICALLY SPECIFIED in the meter, incurring something called distinctive violations of the relevant well-formedness (a.k.a. markedness) constraints. The idea of using markedness constraints to represent lexical items is based on a not widely known phonological theory developed by Golston (1996), which he calls Direct OT, short for Direct Optimality Theory.

According to that theory, the meaningful differences between morphemes can be described using markedness constraint violations, as opposed to using them just to evaluate surface forms (as in the standard OT of Prince and Smolensky 2004). For example, consider the following set of constraint violations, where " $D$ " stands for Desideratum, that is, a markedness violation that partially describes a surface form:

(2) | *Complex Onset | *Complex Nucleus | ${ }^{*}$ Labial | ${ }^{*}$ Lateral | ${ }^{*}$ Continuant | ${ }^{*}$ Low | ${ }^{*}$ High |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| D | D | D | D | D | D | D |

According to Golston (1996, p. 719), the only English morpheme that the set of constraint violations in (2) can represent is the syllable fly [flar], and so those desiderata
describe the lexical specification of that object. ${ }^{2}$ Golston's Direct OT finds a straightforward application in PM: any meter that deviates from perfect rhythm violates some markedness constraint distinctively. I will illustrate shortly how the distinctive violations work in PM; but first, let us review some of the foundations of Golston and Riad's (2000) PM analysis of Greek stichic meters (henceforth abbreviated GR), on which this chapter focuses.

### 6.1.1 Prosodic Greek Metrics

To start with the phonological assumptions of the PM approach to Greek meter, there is independent (i.e., from meter) evidence from phonology that the phonological foot of ancient Greek is the moraic trochee (e.g., Golston 1990; Probert 2006; Gunkel 2014). In metrical phonology (e.g., Hayes 1995), moraic trochee is a strong-weak pattern of two moras (either H or LL) grouped into a foot. It can be visualized formally as follows:

| (3) | x | x |  |
| :---: | :---: | :---: | :---: |
|  | x x | x | x |
|  | $\square$ | \| |  |
|  | H | L | L |

Using Hayes' (1995) linear notation, both structures can be represented more simply as '(x.)', where prominent moras are notated by ' $x$ ', non-prominent ones by '', and foot boundaries by parentheses. I will use this notation throughout the chapter.

Moraic trochee languages construct feet in different ways. In Cairene Arabic, for example, feet are parsed from left to right (Kager 2007). Thus, a word shape such as

[^65]HLLHLLL is parsed (H)(LL)(H)(LL)L with the prominence pattern '(x.)(x.)(x.)(x.)., where the final L is left unparsed ( $(\cdot)$ ) as it cannot form a foot by itself. Ancient Greek, by contrast, is believed to construct moraic trochees from right to left (Allen 1973; Sauzet 1989; Golston 1990; Kiparsky 2003), so that the same shape would in Greek be footed (H)(LL)(H)L(LL) or '(x.)(x.)(x.).(x.)'. Note that in this case, it is the third L from the right which cannot be parsed into a foot. Such unfooted moras incur moraic Lapses (Kager 1993), formalized as violations of *LAPSE. Visualizing the prominence pattern using a Lerdahl-Jackendovian (1983) grid, we can see that a *LAPSE violation (the circled L) corresponds to a ternary rhythm (i.e., strong beats separated by two weak beats):

*LAPSE is complemented by *CLASH, which penalizes adjacent prominent elements, or, in a grid representation, consecutive gridmarks on a (non-final) level not separated by a gridmark on the level below. Importantly, in moraic trochee languages, there can be no moraic clashes, since adjacent moras can never be prominent in a moraic trochee (' $x$ ' is always followed by '?). ${ }^{3}$ Adjacent prominent syllables, on the other hand, are avoided across languages (e.g., Liberman 1975; Nespor and Vogel 1989), and so ${ }^{*}$ Clash can be understood as targeting the syllable level (at any rate, that is how GR use it). In Greek and other moraic trochee languages, *Clash can thus be violated by either $(\mathrm{H})(\mathrm{H})$ or $(\mathrm{H})(\mathrm{LL})$, both of which contain adjacent prominent syllables. A third rhythmic constraint that GR use is what they call Prokosch, or "Stressed syllables are heavy" (p. 117). It expresses the well-known generalization that stressed syllables tend to be heavy, also known as the Stress-to-weight principle (Prince 1990). As concerns the moraic trochee, it is violated by the first syllable of (LL) but not by (H).

Returning to the metrical-prosodic hierarchy shown in (1), consider now what its categories, per GR (p. 104), are traditionally called in Greek metrics:

[^66](5)


As GR emphasize, the prosodic and metrical categories are completely interchangeable, and the metrical units are to be understood as dependent on the prosodic constituents (p. 104). Furthermore, since the phonological foot of Greek is a moraic trochee '(x.)', the rhythmic profile of (5) is the following:
(6) (x.) (x.) (x.) (x.) (x.) (x.) (x.) (x.)

Note that the alternating rhythmic pattern follows directly from the unmarked phonological structure and its eight moraic trochees. This is the basic mechanism by which PM eliminates the grid as a language-external object.

PM takes from Direct OT the idea of using markedness constraints not only to evaluate lines (i.e., to assess their metrical complexity) but also to define meters in terms of their distinctive (intentional) violations of prosodic constraints. Thus, any meter can be defined by the way in which it deviates from unmarked structures like (5) and regular rhythms like (6). A core claim that GR make in their article is that their account offers "surface-true characterizations of each meter, based strictly on the phonology of Greek" (p. 162).

The rest of this chapter argues against this claim. I discuss the meters analyzed by GR one by one, in each case first offering an outline of the PM analysis, followed by critical remarks. GR's original analyses are divided into two parts, the "rhythm part" and the "length part" (p. 100), the former dealing with the rhythmic structures of metra and feet, and the latter with entire verses (e.g., violations of binarity on the line level, as in catalexis). I will focus on the "rhythm part" as the "length part" is not crucial to my argument against PM.

Before moving on to discuss GR's analyses of Greek meters, it is useful to make note of one more seminal idea in PM. As pointed out above, in foot-based theories Greek is assumed to parse feet from right to left non-exhaustively (i.e., leaving some

Ls unparsed). The domain of foot parsing in Greek is usually assumed to be the clitic group (host + enclitic; e.g., Blumenfeld 2004), so that a phrase like kalón estin ("It is beautiful"), where estin is enclitic, is syllabified LLHL and footed '(x.)(x.). ${ }^{4}$ PM, however, neglects by design the prominence structures that are actually found on the surface of verses: GR claim (pp. 109-110) that whatever prominence patterns Greek words and phrases form, they are completely ignored in versification. Instead, GR concentrate on the arrangements of syllable quantities in verse feet and metra (see p. 162, footnote 4), basing their readings of metrical prominence off of the assumed equivalences of the metrical and prosodic categories, as shown in (5). ${ }^{5}$ As will become clear below, this is crucial for understanding how Prokosch, * ${ }^{*}$ Lash and the other rhythmic constraints work in PM.

### 6.2 PM analyses of some Greek meters

### 6.2.1 Anapestic

Anapestic meters, as GR point out, allow any permutation of the set $\{\mathrm{H}, \mathrm{LL}\}$ as valid feet, though LLLL is rare. In other words, MPs in anapests must always be realized as either H or LL, which corresponds to the assumed phonological foot of Greek, the moraic trochee '(x.)'. On the PM approach, this means that anapestic verse feet are unmarked in terms of rhythm, incurring no violations of *CLASH, *LAPSE, or the basic constraint of foot binarity, FTBIN- $\mu$ ("Phonological feet contain two moras"), a moraic version of the more general foot-binarity constraint FtBin. As regards the metrical structure of anapests "nothing more needs to be said" (Riad 2009, p. 142).

GR go on to analyze the relative frequencies of different foot types in Greek authors using ranked rhythmic constraints. They give the percentages of each possible foot in the tragic poets and Aristophanes (pp. 116-117), which are similar to the figures in my 1087-line tragic corpus (see $\S 4.4$ ), listed below:

[^67]| Foot | Count | $\%$ |
| :--- | ---: | :--- |
| HH | 2042 | 47.09 |
| LLH | 1675 | 38.63 |
| HLL | 619 | 14.28 |
| LLLL | 0 | 0 |

Table 6.1: Foot types in tragic recitative anapests
GR first address the preference for HH over the other feet types. As they point out, HH is the only foot type that does not violate Prokosch, since LLH, HLL and LLLL are all parsed into feet such that there is a prominent L syllable. Thus, ranking Prokosch high enough suffices to explain the general preference for HH. Second, why is LLH ( $39 \%$ ) more frequent than HLL ( $14 \%$ )? Because HLL violates Prokosch and in addition incurs a syllabic *Clash violation due to having two consecutive prominent syllables (i.e., H and the first L of LL). Last, the rarity of LLLL is due to the double violation of the high-ranked Рroколсн. In an Optimality-theoretic tableau, the situation looks as follows (GR, p. 118):

|  | anapest | FTBin- $\mu$ | Prokosch | ${ }^{*}$ Clash |
| ---: | :---: | :---: | :---: | :---: |
|  | HH |  |  | $*$ |
|  | LLH |  | $*$ |  |
|  | HLL |  | $*$ | $*$ |
|  | LLLL |  | $* *$ |  |

Tableau 6.2: Anapestic verse feet according to PM
To test empirically for the analysis, we can now use Maxent, which had not yet been adopted in phonological research in 2000 when GR was published. The model needs only include Prokosch and *Clash, since the other rhythmic constraints are never violated. Figure 6.3 is a scattergram of the results, based on my 1087-line corpus. Not surprisingly, the model achieves a good fit, and the obtained weights of the constraints match GR's ranking (Prokosch: 1.79, *Clash: 1.32). The only problem is that the zero-frequency LLLL is predicted to have around 240 occurrences (the dot near the bottom left corner of the scattergram). But this, too, might have been expected, since (as GR acknowledge on p. 118) Prokosch can only predict that LLLL is less common than HLL and LLH but not that it is marginal at best. The model can be made perfect


Figure 6.3: Scattergram for verse feet in anapests (PM analysis)
$\left(R_{a d j}^{2}>0.999\right.$ with a diagonal regression line) by adding a constraint that penalizes LLL sequences (see Steriade 2018, for phonological and metrical evidence for such a constraint in Greek; and §3.4.4 of this dissertation). But the model now has three constraints and four candidates, making it more a description rather than a genuine explanation of the relative frequencies.

### 6.2.1.1 Critical remarks

One of the primary claims that GR make is that their framework gives "surface-true" characterizations of Greek meters (e.g., p. 162). This is meant in the sense that their analyses use exclusively the actual arrangements of $L$ and $H$ syllables in verses without needing to stipulate abstract patterns underlying those arrangements. In addition, the approach is based strictly on the assumed moraic trochee foot structure of Greek, which the authors "put [...] into the meter and read the result off of the syllabic prominences" (p. 130).

But precisely the way in which GR "put" the moraic trochees into meter casts some doubt on this main claim. As pointed out above, according to the moraic trochee account of Greek phonology, words are parsed into feet from right to left, meaning
that word-final single Ls are left unparsed, as for example in én.tâ̂.tha (= "here", LSJ, s.v.), which is parsed as '(x.)(x.).. Consider the following anapestic dimeter line (Aeschylus, Persians 34):
(7) Neîlos épempsen: Sousiskáānes

H L L H H H H H H
"The Nile sent forth Sousiskanes"

Assuming that the domain of foot parsing in Greek is the clitic group (see $\S 6.1$ above), the moraic prominence profile of (7) is '(x.). .(x.)(x.) (x.)(x.)(x.)(x.)'. Note that the final L of Neîlos and the initial L of épempsen cannot be parsed into feet. According to GR, however, any valid anapestic dimeter pattern has the regular metrical prominence structure '(x.)(x.)(x.)(x.)(x.)(x.)(x.)(x.)'; In other words, lines of verse must have two contradictory parses of moras into feet, each with different violations of the relevant constraints.

|  | Neîlos épempsen: Sousiskānēs | FtBin- $\mu$ | Prokosch | ${ }^{*}$ Clash |
| :--- | :--- | :---: | :---: | :---: |
| phonology | $(\mathrm{H}) \mathrm{L}, \mathrm{L}(\mathrm{H})(\mathrm{H}),(\mathrm{H})(\mathrm{H})(\mathrm{H})(\mathrm{H})$ |  |  | $* * *$ |
| PM | $(\mathrm{H})(\mathrm{LL}),(\mathrm{H})(\mathrm{H}),(\mathrm{H})(\mathrm{H}),(\mathrm{H})(\mathrm{H})$ |  | $*$ | $* * * *$ |

Tableau 6.4: Two metrical parses of Aeschylys, Persians 34
Tableau 6.4 shows the two parses of (7). As can be seen, the phonological and metrical (according to PM ) prominence patterns incur different violations of РRoкоsch and ${ }^{*}$ Clash. In this case, the difference is due to the first three syllables Neî.lo.s é-: the phonological parse '(x.).' does not incur any violations of either constraint, whereas its metrical counterpart HLL violates both constraints once. As has been seen, HLLshaped feet in the anapests do always violate both Prokosch and *Clash, due to the way in which GR assign prominences directly to MPs (H or LL $=$ '(x. $)^{\prime}$, $\mathrm{L}={ }^{\prime}$ '). Summarizing, the need for simultaneous contradictory prosodic structures in PM calls into question the sense in which it the theory claim to be "surface-true".

Furthermore, it is not obvious why the constraints should be confined to verse feet. One of the key points GR make at the outset of their paper is that for metrical purposes, Greek verses are parsed like long words, which gives them their characteristic quantitative profiles (p. 111). According to GR, this is an effect of the general re-ranking of phonology over syntax in meter, where syllabification "freely overrides


Figure 6.5: Scattergram for metra in anapests (PM analysis)
morpheme and word boundaries" (p. 112). But based on this assumption, arguably also the prominence structures in meter should be parsed from larger domains than verse feet. As explained in §4.4, the basic building block of anapestic meters appears to be the metron, whose edges are commonly matched with word boundaries; plausibly, then, the domain where Prokosch and *Clash should have the most effect on statistical tendencies is not the verse foot, but the metron. At stake is whether *Clash is also avoided at the foot boundary within metra, penalizing the patterns $\ldots(\mathrm{H}) \mid(\mathrm{H}) \ldots$ and $\ldots(\mathrm{H}) \mid(\mathrm{LL}) \ldots$ at the foot juncture (indicated with |), in addition to being avoided within verse feet.

The scattergram in Figure 6.5 shows the fit of a Maxent model that tried to match the frequencies of the sixteen possible variants in my 1087-line corpus, using the Golston-Riadian Prokosch and *Clash, augmented for metra. As the plot reveals, the constraints effectively fail to predict the relative frequencies of the metra. However, this might be due to the fact that the model cannot explain the marginality of LLLL in the data, something which GR admit is a deficiency in their framework as it stands (p. 118). For the benefit of the doubt, then, we can see if including *LLL (see


Figure 6.6: Scattergram for metra in anapests (PM analysis), with *LLL
§3.4.4) in the model achieves better results. As Figure 6.6 shows, this second model does fare better $\left(R_{a d j}^{2}=0.870\right)$, but visual inspection of the scatterplot indicates that it is still far from being satisfactory. In sum, it it not obvious that GR's analysis does much more than describe the allowable foot types in the anapests in terms of (arguably somewhat ad hoc) constraints and dubious metrical parses.

GR emphasize that what matters in Greek meter is strictly syllable weight, not stress (GR, p. 110): "we ought not to understand Greek meter in terms of stress" (p. 111). But are not violations of Prokosch or *Clash descriptions of stressed syllables in different contexts (see p. 117, where GR define the constraints)? Perhaps the focus of the analysis should then be on quantity modulation instead of stress; but in that case, *Clash and *LAPSE would have to be implemented in a different way. As Topintzi (2008) points out, purely quantitative counterparts of these constraints would be useful in phonological analysis (see also Steriade 2018). She formulates them as follows:
(8) *CLASH- $\mu$ "Adjacent heavy syllables are prohibited, i.e., *HH"
*LAPSE- $\mu$ "Adjacent light syllables are prohibited, i.e., *LL"

Evidence for *Clash- $\mu$ and *LAPSE- $\mu$ come from various languages and processes (e.g., iambic shortening, trochaic lengthening), where stress plays no role. But as Topintzi's definitions indicate, such constraints would penalize just unmodulated weight patterns, unlike GR's *Clash which is also violated by HLL. So something other than pure syllable weight must play a role in the PM analysis of Greek meter- namely, the structuring of moraic and syllabic prominence.

GR claim that on the syllabic level, anapestic meter looks "chaotic, as if it had no rhythmic properties at all" (GR, p. 113). But this would seem to be just not true: as my analysis of anapestic dimeters in $\$ 4.4$ suggests, the rhythmic profiles of anapests - though not as evidently "rising" as traditionally thought-are far from being chaotic. GR appear to think that in order for a meter to be rhythmic, it needs to be uniform: "The lack of a uniform pattern of syllable weight means that any syllabic characterization of anapestic as rising, weak/strong, offbeat/beat, or the like is bound to fail" (p. 114). But such a requirement would mean that hardly any type of verse in the world could be described in terms of metric periodicity, since most meters allow for some rhythmic variation at the surface (a rare exception being the Persian mutaqārib meter; Hayes 1979). Not many poets would probably agree that they compose mainly arrhythmic metrical verse.

Finally, GR point out (p. 157) that the traditional analysis of the anapestic meters as "rising" is probably partly based on the fact that the last full foot of catalectic lines is typically LLH. The catalectic line usually corresponds to the end of a syntactically bounded line-group (e.g., Korzeniewski 1968, p. 87). For instance, the last line of Euripides' Medea reads as follows: toiónd' apébee tóde prâgma ("Such is the outcome of this story"), or (HH) (LLH) (LLH) (H-). The regular anapestic ending of these lines could plausibly be interpreted as a final strictness effect (§1.3.3), and so-as GR suggest - taken to mean that the basic rhythm of this meter, despite all its flexibility, is indeed "rising" (see also §4.4.8).

However, GR claim that we do not actually know whether it is the final or the initial position of the catalectic line that is gone missing (pp. 157-158). On the headless analysis, the last line of Medea, for example, would be scanned as (-H) (HLL) (HLL) $(\mathrm{HH})$, quite an unusual pattern (in my dataset of acatalectic anapests, the sequence (HLL) (HLL) occurs only 20 times and only within metra). In any case, there are at least two good reasons to believe that the catalexis is line-final, as traditional wisdom would have us believe. The first is the principle of saliency (see §1.3.6), which Hayes
and MacEachern (1998, p. 485) define as follows: "a metrical constituent is salient if its final cadence is more cadential [i.e., shorter] than all of its nonfinal cadences, and if all its other cadences are uniform". This is exactly the case of anapestic periods: a number of dimeters with a uniform (acatalectic) cadence is typically followed by a catalectic (i.e., cadential) line. The other reason to believe that the final position is missing is that catalectic lines, just like acatalectic ones, regularly have a word boundary after the first metron, as in the above example: (HH) (LLH) | (LLH) (H-). Making the first position catalectic would move the break into the middle of the third foot: $(-\mathrm{H})$ (HLL) $(\mathrm{H} \mid \mathrm{LL})(\mathrm{HH})$. To sum up, there seems to be no good reason to doubt the traditional analysis of the catalexis as line-final.

### 6.2.2 Iambic

As we have just seen, anapestic meters are unmarked in PM with regard to FTBin- $\mu$ because every position in the meter is strictly bimoraic. Iambic meters are different: they are based on the metron traditionally notated as $\times-\cup-$, where $\times$ and - can have 1 or 2 moras but $\smile$ must always be monomoraic (except in comic iambs; see $\S 6.2 .2 .1$ below). The obligatory $L$ in the iambic metron leads GR to the rather striking conclusion that iambs in Greek are characteristically arrhythmic (p. 139).

This is justified by GR as follows. If a metrical position is H or LL, its prominence pattern is always '(x.)'; this is due to the characteristic foot parsing mechanism of PM, as explained above. By the same token, any MP realized as L will be ' $\because$, an unfooted non-prominent mora. Consequently, any valid iambic metron will have at least one moraic lapse due to the third position being invariably L. To illustrate, here are some of the possible variants of the iambic metron:
(9) HHLH (x.)(x.).(x.)

LHLH .(x.).(x.)
HLLLH (x.)(x.).(x.)
LLLLH .(x.).(x.)
HHLLL (x.)(x.).(x.)
LHLH (x.)(x.).(x.)
LHLLL .(x.).(x.)

Every variant of the iambic metron, without exception, ends in the sequence '(x.).(x.)' with a moraic lapse. According to GR, the fact that iambic trimeters incur distinctive violations of ${ }^{*}$ LAPSE three times per line defines the rhythmic (or indeed arrythmic) character of this metrical form.

Continuing to the frequency-matching side of GR's analysis, the rarity of LL is again accounted for by Prokosch, which penalizes stressed L syllables, and the preference for HHLH vs. LHLH is due to FTBIN- $\mu$. In addition, GR include ${ }^{*}$ CLASH in their analysis, though its role here is not elucidated (see above for the definitions of these constraints). Below is the relevant frequency-matching tableau (from GR, p. 140), with the frequencies of the different metra in my 3274-line iambic trimeter corpus shown in the rightmost column. The ' I ' in the *LAPSE column is shorthand for 'iamb', indicating a distinctive violation:

| iamb | *LAPSE | Prokosch | FtBin- $\mu$ | *CLASH | Frequency |  |
| :---: | :---: | :---: | :---: | :---: | :---: | ---: |
|  | $(\mathrm{H})(\mathrm{H}) \mathrm{L}(\mathrm{H})$ | I |  | $*$ | $*$ | 4736 |
|  | $\mathrm{~L}(\mathrm{H}) \mathrm{L}(\mathrm{H})$ | I |  | $* *$ |  | 3413 |
|  | $(\mathrm{LL})(\mathrm{H}) \mathrm{L}(\mathrm{H})$ | I | $*$ | $*$ |  | 48 |
|  | $(\mathrm{H})(\mathrm{LL}) \mathrm{L}(\mathrm{H})$ | I | $*$ | $*$ | $*$ | 172 |
|  | $(\mathrm{H})(\mathrm{H}) \mathrm{L}(\mathrm{LL})$ | I | $*$ | $*$ | $*$ | 74 |
|  | $\mathrm{~L}(\mathrm{LL}) \mathrm{L}(\mathrm{H})$ | I | $*$ | $* *$ |  | 96 |
|  | $\mathrm{~L}(\mathrm{H}) \mathrm{L}(\mathrm{LL})$ | I | $*$ | $* *$ |  | 37 |

Tableau 6.7: Iambic metra according to PM

In my dataset, the Prokosch-respecting patterns HHLH and LHLH together account for the vast majority of metron types (about $95 \%$ ); GR report similar figures (p. 140). Among the rest of the candidates, those that violate FtBin- $\mu$ just once are more frequent (294) than those that violate it twice (133). As expected, a Maxent analysis with just these two constraints suffice to model the frequencies of the seven listed metron types accurately $\left(R_{a d j}^{2}>0.999\right.$, Prokosch: 3.90, FtBin- $\left.\mu: 0.33\right) .{ }^{6}$

[^68]
### 6.2.2.1 Critical remarks

I offer three criticisms of GR's analysis of Greek iambs. First, and most importantly, GR's treatment makes incorrect predictions about the statistical tendencies of iambic trimeters at the line level. Specifically, invoking FtBin- $\mu$ is at odds with the fact that though anceps positions in the trimeters are on average more often realized as H than L , the opposite holds true of the line-final anceps position (see §4.2.1). This can be plausibly analyzed as a final strictness effect (§1.3.3), a putative metrical universal (Ryan 2019, p. 139). From the perspective of PM, however, iambic trimeter lines get less regular towards line-end, since there are more FtBin- $\mu$-violating patterns (i.e., LHLH) there than elsewhere. Unless violating FtBin- $\mu$ at the clausula is understood as an anti-rhythmic preference similar to the distinctive *LAPSE violations, the PM analysis wrongly predicts that HHLH should the preferred shape line-finally.

Second, GR concentrate their analysis on a specific variant of the iambic verse form, used by Archaic poets and tragic playwrights, in which the $\smile$ must indeed be realized as L without exception. However, the comic poet Aristophanes uses another variant where the breve can be exceptionally written as LL (West 1982a, p. 88), avoiding the distinctive *LAPSE violation. In other words, comic iambic trimeters are in the light of PM more rhythmic than Archaic and tragic lines. This is highly doubtful, since all the other evidence (e.g., lack of regular word-breaks, greater frequency of resolution; see ibid., pp. 88-90) indicates that comic trimeters are in fact rhythmically much freer than Archaic and tragic lines.

Finally, the "surface-truth" of the PM approach is again called into question by the way in which GR parse metrical positions into feet. Particularly worrying is that the line-initial syllabic sequence LLLL can be footed differently depending on the metric context: as an anapestic foot, LLLL is parsed as '(x.)(x.)', but as the beginning of an iambic metron, it is ‘.(x.)? (see (9) above). If we strictly "base our dums and dis on quantity" (GR, p. 110), which of the two prominence patterns is correct? (The answer: not necessarily either, because the actual feet of Greek words can be entirely different, as discussed above in §6.2.1.) On the other hand, taking seriously GR's idea of basing rhythm on pure quantity, LLLL should arguably be treated as an undifferentiated series of time intervals, whose metric organization is a perceptual phenomenon (see §2.2.2). As cognitive psychologists have long known (e.g., Bolton 1894; Brochard et al. 2003),
such sequences of equal time events are usually perceived as rhythmically alternating, that is, either '(x.)(x.)' or '(.x)(.x)', but rarely if ever '.(x.)..'

### 6.2.3 Dactylic-spondaic

The hexameter is typically analyzed as having six feet, each of which can be either HLL or HH, except the last one, which is HH. The version offered by GR is simple: they first parse the verse feet as if they were pairs of phonological feet, and then note that both HLL and HH, having the prominence structure '(x.)(x.)', involve exactly one (syllabic) *Clash violation. What this means is that any variant of the hexameter will have exactly six *Clash violations, which GR take to be distinctive for this meter. In addition, GR point out that HLL are generally more frequent than HH. According to GR, this is due to the constraint FtBin- $\sigma$ or "Phonological feet (= metrical positions) contain two syllables" (e.g., Prince and Smolensky 2004). HLL violates it once but HH does twice; this then accounts for the higher frequency of HLL.

### 6.2.3.1 Critical remarks

As regards * Clash and its interpretation in the PM framework, we can summarize the issues already pointed out in the above sections: 1) in the actual foot structures of Greek words and phrases, not all LL sequences will violate *CLASH; 2) alternatively, if lines are understood as being parsed as single "long words", *CLASH will also be violated at foot boundaries, not just foot-medially; 3) if *Clash penalizes only Topintzian nonmodulated weight patterns (as it perhaps should, if the focus is on syllable quantities), HLL does not incur a violation.

But the invocation of FtBin- $\sigma$ introduces a new problem. We have seen that GR often make use of the moraic version of the foot binarity constraint, FtBin- $\mu$. If Greek indeed is a language that constructs feet using moraic trochees, as is commonly believed, the use of FtBin- $\mu$ in meter may be motivated phonologically. Recall that PM is based on the assumption that "prosodic concerns are given unusually privileged status in poetic meter" (p. 103). But is FtBin- $\sigma$ a "prosodic concern" for the speakers of ancient Greek, if their language uses moraic instead of syllabic feet? The assumption that constraints are universal (GR, p. 132) may help motivate the inclusion of FtBin$\sigma$, but it also arguably makes the analysis too powerful. To quote from a more recent PM-based analysis of Tashlhiyt Berber meters (Riad 2017), picking constraints from a universal inventory "runs the risk of losing the connection between the individual
language and the meter occurring in it". It has sometimes been proposed that Greek uses syllabic trochees (Steriade 1988; Noyer 1997) instead of moraic ones. Should that alternative analysis turn out to be correct, PM could plausibly invoke FtBin- $\sigma$ (but not FTBin- $\mu$ ).

### 6.2.4 Other meters

Two more meters are discussed by GR: the trochaic tetrameter catalectic and a rare spondaic meter that only contains HH-shaped feet. GR formalize the latter as incurring a double violation of FTBin- $\sigma$ and one of *CLASH, which have already been discussed above. As for the trochaic tetrameters, GR analyze them as headless iambic tetrameters (-HLH XHLH XHLH XHLH), which would differ from iambic trimeters only in that they violate ${ }^{*}$ LAPSE distinctively four instead of three times. ${ }^{7}$ The general points I have raised above about the PM approach to Greek meter apply to these other meters just as well.

### 6.2.5 Meter as a prosodic morpheme

As we have seen, PM strongly advocates the idea that the hierarchical organization of meter is modeled after the phrase structure of ordinary speech-or indeed, that it is a particular version of it. Until recently, however, PM theorists had not clarified how a metrical structure, conceived of as a pure prosodic hierarchy without segmental content, comes about. Riad (2017) takes this next step by arguing that meter is a kind of prosodic morpheme (e.g., McCarthy and Prince 1986, 1994; Downing 2006). Briefly, whereas normal morphemes are autonomous strings of segments (or subsegments) with a meaning or grammatical function, the class of prosodic morphemes is better characterized as having a constant shape and content that depends on some other morpheme. An example is reduplication: in many languages, words are produced by copying a part of the stem (e.g., in Diyari: from tjilparku is formed tjilpa-tjilparku "bird species"). What determines the shape of the reduplicant (and other morphological constructs such as nicknames and infixes) has attracted a great deal of discussion (see Downing 2006 for a bibliography). According to the widely followed Generalized Template Theory (McCarthy and Prince 1994), it is due to the re-ranking of the same constraints

[^69]already active in the language's phonology. In Diyari reduplication, for example, the copied part constitutes a single stress foot whose disyllabic shape corresponds to the minimal prosodic word in this language (ibid.). In general, prosodic morphemes tend to exhibit unmarkedness, which in constraint-based analyses has been accounted for by ranking the base-copy faithfulness constraints below the markedness constraints, allowing for the emergence of unmarked structures in the copied segments.

To return to meter, Riad (2017) conjectures that the similarity between meter and prosodic morphemes is not coincidental; indeed he argues that meters are prosodic morphemes, as both tend towards unmarkedness (binarity, eurhythmy, syllabic simplicity) and are built from authentic prosodic units (cf. Blumenfeld 2015). Three arguments against this idea are sketched below.

First, prosodic morphemes are commonly assumed to be maximally bimoraic or disyllabic. Meters, on the other hand, can in PM be as large as a full intonational phrase. Riad (2017) acknowledges that analyzing meters as prosodic morphemes requires making the additional assumption that meter is a much larger entity than all known prosodic morphemes; and it is not evident that this assumption can be substantiated. Riad cites Ghomeshi et al. (2004) as providing evidence for prosodic copying of units larger than feet; but the authors of the paper themselves say that the phenomenon they discuss (contrastive focus reduplication in English) "cannot be defined in prosodic terms" (p. 310), as it also involves morphosyntactic, syntactic and lexical factors. In prosodic copying, size really appears to be an obstacle.

Second, PM parses feet differently from prosodic morphology. In prosodic morphology, what is parsed into feet are the actual segments that are first copied from the base, and it is the job of the ranked constraints to determine the optimal parsing into feet. In PM, by contrast, the foot structure is blind to the actual phonological segments, as has been seen above. As Riad (2017) points out, simultaneous prosodic structures where the shape of the target and the actual output are different from each other are not unknown in phonology, but there is no evidence that two different foot structures can coexist in the same structure simultaneously.

Third, as Downing (2006, p. 8) points out, prosodic words are not widely attested to have a maximal (binary) size in the world's languages. One might then call into question, following Downing (ibid., p. 37, footnote 1), if the existence of the universal constraint WdBin is well motivated, and consequently, whether the binary branching nature of many meters is best analyzed in prosodic terms. Although binary rhythms
and grouping structures are certainly favored across human cultures (see §2.2.2.1), they are plausibly manifestations of more general cognitive biases, as discussed in Chapter 2.

### 6.3 Summing up

Prosodic Metrics eliminates metrical templates as language-external objects by generating metrical structures directly from ranked phonological constraints. To achieve this, it needs to formalize the marked properties of meters as distinctive violations of well-formedness constraints in the style of a nonstandard and (so far) uncorroborated phonological model (Golston 1996). Another essential but controversial feature of PM is its non-iterative foot parsing mechanism. The invariable treatment of non-empty metrical positions in Greek verse as either moraic trochees (H and LL) or unparsed syllables ( L ) amounts, as I have argued, more to description than analysis. It also contradicts the purported "surface-truth" of PM, as the lapses and clashes that PM uses to characterize meters are read off of locally parsed prosodic patterns that sometimes contradict the actual prominence structures of lines. Furthermore, the assumption that non-binary metrical positions (i.e., ৩) violate FtBin- $\mu$ implies (contrary to previous studies) that Greek iambic trimeters get more complex towards the end of the line, and that Aristophanes made the iambic trimeter more regular by introducing resolution in $\checkmark$ positions. In their account of the Greek hexameter, GR need to invoke FtBin- $\sigma$, a constraint of unknown provenance in Greek phonology. Finally, the claim that Greek anapests are "quite chaotic" (GR, p. 157) is simply not true, unless by "chaos" is meant the lack of perfect syllabic uniformity that characterizes meters across languages.

## Chapter 7

## Discussion and conclusions

This dissertation has been an attempt to start telling a different story about ancient Greek versification than the usual one; one that goes beyond the identification of syllabic patterns in Greek verse to explain what led poets to arrange the syllables just in those ways, instead of some other ways. A main premise behind this search of explanation has been that meter in poetry is not (just) a cultural construct, but a regimented correspondence between a hierarchic metrical structure internalized by the poet and its partial manifestations in patterns of verse. Although the idea that meter is an abstract rhythmic pattern is not new in metrics, it is at odds with the traditional treatment of ancient Greek meter in classical scholarship, which has tended to identify meter with the durational patterns found in the texts. In addition, the present approach has involved bringing together some of the research that has accumulated in in comparative metrics, rhythm cognition, and statistical linguistics, to shed new light on Greek meter. This chapter summarizes the main results of the study, discusses them in the broader context of metrical scholarship, and considers some ideas for further research. I start by going back to the roots of classical descriptivist metrics-namely, Nietzsche.

### 7.1 Nietzsche's legacy: Greek meter is arrhythmic

In 1870, Nietzsche claimed to have found "a new metrics" (eine neue Metrik; published in Nietzsche 1986, p. 159), which dismantled the anachronistic reading of an ictus (i.e., dynamic stress) into Greek language and meter that his contemporaries had favored; as he writes, "the development of the equation of Takt ["rhythmical beat"] and [metrical] 'foot', above all the theory of ictus, is the history of modern rhythmics" (Nietzsche 1993, p. 269, original emphasis, tr. Porter 2000, p. 336). In Nietzsche's reading of ancient
metrical theory, the Greeks had a unique way of perceiving rhythm that involved only durations and their categorization into simple time-ratios (1:1, $1: 2,2: 3$ ). The Aristoxenian arsis and thesis, which could be assigned to either term of the ratios, had (says Nietzsche) nothing to do with dynamics but were simply a way of marking time, necessary precisely because of the lack of dynamic contrasts in the Greek language (Halporn 1967, pp. 239-240). Crucially, for Nietzsche, sequences of feet (i.e., verses and larger periods) are not rhythmic structures at all, because the time-markers only pertained to the basic time-ratios within feet, and "only that which can be measured in time falls within the realm of rhythm" (Nietzsche 1993, p. 164, original emphasis, tr. Porter 2000, p. 142).

While revisionist at the time, Nietzsche's strict durationalism was adopted almost wholesale by much of 20 th century work in Greek meter, and persists even today as the mainstream view in classical scholarship. According to Maas (1962), who abstains from all rhythmic analyses beyond pure observation, modern "'dynamism' colours also the otherwise quantitative rhythm of our music", and so we can never know "Greek poetry as it actually sounded" (pp. 3-4). West (1992), who is less negative as to the reproducibility of Greek rhythms, nevertheless denies that they had anything like the regular bar-lengths of Western music and argues instead for an "additive" system where bars and time-signatures may change abruptly (pp. 131-135), echoing Nietzsche's ideas of the irregularity of Greek rhythm. Michon (2016) summarizes the mainstream view well: "far from consisting of a more or less regular succession of weak and strong beats, [...] [Greek] rhythm was composed of irregular and asymmetrical temporal elements of various durations".

The alleged volatility of Greek meter is ultimately based on a simple idea: "ordinary everyday speech itself [...] could very easily contain perfect verses" (Nietzsche's letter from 1888 , tr. Porter 2000, p. 149). In other words, verse rhythm is not only rooted in language; it is a kind of linguistic rhythm. Nietzsche's reasoning appears to be that since ancient Greek had no linguistic stress, it can have had no metrical beat eitherand because the rhythm of ordinary speech is anisochronous, so must verse rhythm be. Again, these ideas are echoed in current Greek metrics. For instance, the syllabic figure $-\cup \cup$, which is both the basic metron in Homeric hexameter and a rare resolved variant of an iambic foot, is standardly treated as the same rhythmic figure regardless of context; a dactyl is a dactyl, whether mouthed by a stage actor, rhapsode or an orator. This is a consequence of the fixation on pure observation of syllabic patterns,
as advocated by Maas (1962), though responsion suggests it is false. On the other hand, West (1982a) does differentiate between the rationalized rhythms of song and the more fluctuating ones of ordinary speech and recitation; but even music has "a certain [rhythmic] flexibility" (p. 25) due to the existence of the anceps $(\times)$ position, which he interprets as having a variable length.

This is not to say that traditional metrics generally denies the existence of a musical beat in Greek verse. Dale (1968), for instance, says that the quantitative patterns may in some cases have been "reinforced [...] with some kind of dynamic beat" (p.5), and the Greek practice of clapping hands or beating feet to music is well known (West 1982a, p. 22). But it is seen as a secondary phenomenon, a potential "underlining" of quantitative meter (Dale 1968, p. 5) and something that follows the durational patterns instead of being an organizing principle behind them. To apply Lotman's (2008) useful distinction, traditional metrics adopts an a posteriori approach to meter, seeing meter as an "immanent quality" of texts (p. 33), whereas according to an a priori approach meter would be seen as something that precedes the texts and organizes it. Since the traditional view is rooted in classical philology, whose main goal has always been to establish knowledge about ancient texts (Thomas 1990), it is understandable that meter, too, has been studied as an inherently textual object. In Barker's (1991) summation, meter is "an ordering of lengths, [...] present in any poetic arrangement of letters, syllables and words. Rhythm is not: it is brought to the words" (original emphasis, p. 72). As something subservient to meter, rhythm is understood as a "matter of convention or arbitrary choice" (West 1982a, p. 23).

### 7.2 A different perspective

As the preceding section showed, the rhythm-meter dichotomy of traditional Greek metrics (itself rooted in ancient theory; e.g., Mathiesen 1985) has been consistently presented as an opposition between textual regularities ("meter") and their manifestations in performance ("rhythm"). In this dissertation, these concepts have been used in a different way. Instead of conceptualizing meter in poetry as a disembodied social or cultural object, the main question here has been what cognitive representation of rhythm underlies the metrical practices of Greek poets. Of course, we can never be sure of the psychological underpinnings of what remains of Greek verse rhythm - and it may be just this "empirical discomfort" that has led literary-historical metrists to
avoid these questions (Kiparsky 1984, p. 38). But evidence that has accumulated in cross-linguistic research in metrics and the psychology of rhythm can at least point the way.

The big picture that has emerged is that meter in both poetry and music (and more debatably, also ordinary speech) is a hierarchic rhythmic gestalt where the perception of relative prominence (i.e., relatively stronger and weaker beats) plays a central role. Although non-metrical verse traditions have existed even before the emergence of vers libre in the 19th century (e.g., Gregorian chant; Temperley 2001, p. 297), the evident surface regularities of Greek verse, together with ancient testimony, strongly suggest that most Greek verse forms are far from lacking such a metrical organization. It can be added that metrically simple verse is exhibited across cultures (Burling 1966), and that even non-isochronous meters tend to be periodic at some metric level (Temperley 2001; London 2012; and Chapter 2 of this dissertation). From the cognitive perspective, the perennial question of whether Greek poetry was characterized by an ictus (i.e., accent) is moot: the metric accentuation of rhythmic patterns is a perceptual phenomenon, just as the Greek rhythm theorist Aristoxenus (4th c. BCE) already seems to have understood (Elements of Rhythm 12; 16; 20, etc.). Furthermore, as London (2012, p. 4) points out, meter perception is not just stimulus-driven, but also a matter of fitting "patterns of events in the world to patterns of time we have in mind". It does not seem implausible to assume that composing Greek poets had some such patterns in mind, rendered concrete by the arrangements of words that have survived to the present.

The just sketched view of meter is standard in music psychology (e.g., Kotz et al. 2018) and generative metrics, a branch of verse theory whose origins are in 1920's Russian formalism (Rudy 1976). According to one early formulation, in "creating the design of a poem, the poet has stored in his mind a metrical scheme, which he feels to be a kind of rhythmic-melodical contour, a framework into which words are 'inserted"' (Tomaševskij 1923, p. 83, tr. Červenka 1984). In this approach, the abstract pattern and its relationship with surface manifestations become the central object of investigation, replacing the devising of metrical "dictionaries" of traditional (Greek) metrics (Kiparsky 2018). As the early formalists intuited, the repeated patterns of metrical verse give rise to an expectation of rhythmic regularity that a participant in a metrical tradition can sustain without any conscious effort, and deviations from the expectation are not felt as pertaining to individual verses but to the expectation itself.

More recently, experimental work, including brain-imaging studies, has confirmed that the metric expectation is a real phenomenon of the "rhythmic brain" (e.g., Haegens and Zion Golumbic 2018). Although the brain can also synchronize to the rhythms of ordinary speech, the stricter regularities of music and metrical verse allow for more accurate predictions (Schön and Morillon 2018). In this sense, an accidental verse embedded in a prose text is not a verse at all, simply because it lacks a metrical intent behind it.

### 7.3 Meter is not pure phonology

Early formalists criticized the then prevalent "acoustic metrics" of Sievers (1893, 1912), according to which meter was a sound pattern predetermined entirely by the poet (and which a trained Autorenleser could reproduce). Instead, they argued that the "experiment" in metrical analysis is strictly the text as a linguistic object, and that consequently, meter itself should be seen as a purely linguistic phenomenon (Červenka 1984). This line of though culminated in Jakobson's famous paper " Linguistics and poetics" (1960), a core claim of which was that poetry is not just a figure of sound but a projection of linguistic sames to a combinatory "axis" where a syllable is contrasted to another syllable, stress to another stress, quantity to quantity, and so on. In this vision of meter, all of poetic structure turns into "linguistic oppositions and correspondences, symmetries and anti-symmetries, equivalent forms and salient contrasts", as E. J. Brown (1983, p. 97) puts it. The limits of metrical analysis are thus only bound by those of linguistics, and, as is well known, Jakobson defined the boundaries of linguistics "in the broadest possible way" (Kiparsky 1984, p. 27). The program that Jakobson initiated has been hugely influential in generative metrics, where it has been developed further, paralleling (and sometimes contributing to) the evolution of linguistics more broadly.

A common view in contemporary generative metrics has been that meter is a phonological entity (e.g., Fabb and Halle 2008; Blumenfeld 2015; Riad 2017; Kiparsky 2020). This dissertation has argued that though the material of poetry is obviously language, and though some poetic genres may be closer to speech than music, the meter-asphonology hypothesis is unlikely to be generally true. One should perhaps first ask, as I have suggested, what it would mean to "describe [poetic meter] from a purely linguistic point of view" (Jakobson 1960, p. 365), or more generally, for something to
be "purely linguistic". It is clear that language shares with other cognitive domains some of its core properties such as memory, combinatoriality and recursivity, as well as the formation of expectations (Jackendoff 2009). Although poetic meter depends on phonological categories, such as stress, quantity and phrasing-these being the tools that language delivers to poets-these categories themselves involve many properties non-specific to language. For instance, the well-known fact that stress is attracted by heavy syllables is closely paralleled by the fact that long notes are attracted to strong musical beats. The heterogeneous nature of phonology has been acknowledged at least since the 1980's (e.g., Nespor and Vogel 1986); and as far as representations of rhythm such as metrical grids are used in phonology or poetic metrics, they are not "strictly speaking a linguistic representation at all" (Hayes 1984, p. 65), plainly because rhythm itself is extra-linguistic. Moreover, although the grids used in phonology are formally homologous to those used in music and poetic metrics, cognitively they must be distinct, as the former describe the rhythms of individual utterances, whereas the latter denote continuous metrical expectations. The presence of syncopation and silent beats in poetic meter-and their non-existence in ordinary language - is, as I have argued, a further indication that poetic meter is closer to musical meter than linguistic rhythm.

This dissertation has also argued against another hypothesis of generative metrics, according to which the apparent hierarchical group-structuring of poetic meter is homologous to the grouping structure of speech utterances (i.e., the prosodic hierarchy). One problem in this equation, as I have pointed out, is that the grouping structures in speech and meter appear to be connected to the grid in different ways. In ordinary phonology, metrical grids are standardly seen as products of a secondary mapping from the prosodic hierarchy (itself a mapping of morpho-syntactic structure), where each gridmark acts as the sole head of some group. According to the principle of culminativity, each domain in the hierarchy must be headed in this way. If meter is a prosodic hierarchy, it appears to be severely underspecified (Blumenfeld 2015, p. 90), as evidence for more than two or three levels of prominence in poetic meter is hard to find. Ancient Greek offers an interesting additional argument against the tangling of grids and groups in meter: Greek meters tend to anti-align phrases with respect to its grid periodicities. This implies that grids and groups must be separated in Greek verse, and importantly, this separation is also fundamental for music (Lerdahl and Jackendoff 1983), but impossible in standard Prosodic Hierarchy theory. Secondly, if metrical groups are just metonyms for phonological categories, the former should arguably be
somehow evident in the matching linguistic category; for instance, verse feet should be matched with phonological feet, and metra with prosodic words. But even though metrical groupings are to an extent "echoed" by phonological phrase structures, there is little evidence for such level-to-level matching. Finally, I have also pointed out that the grouping structures of poetic meter and language are far from being unique to phonology, but can be analyzed in more general Gestalt-psychological terms. Again, then, it can be argued that grouping in poetic meter is not a "version" of linguistic grouping but an instantiation of some more general cognitive process.

As Kiparsky (1984, p. 36) points out, a key principle of Jakobsonian metrics-the abstract template itself-is also its most problematic part. There is no known linguistic parallel to an architecture in which variable surface forms are matched and evaluated against metric patterns; in music (and, arguably, metrical poetry) it is the norm. The metrical work of Golston and Riad (1994 et seq.) and colleagues tries to simplify metrics by doing away with the template, instead making meter a matter of constraint interaction at the phonological surface of lines. In my criticism of this approach (Chapter 6), I have tried to show that the theory of Prosodic Metrics (as it is called) cannot abolish metrical templates convincingly. As I have argued, the theory relies on a non-standard version of Optimality Theory not without its inherent problems, and uses a unique non-iterative procedure to parse Greek verses into sequences of moraic trochees and unfooted moras. The theory also creates typologically suspect predictions, such as that Greek verses get more irregular towards the ends of lines, and that the Greek metrical system as a whole is fundamentally arrhythmic (resembling Nietzsche's ideas in this respect). The upshot of my criticism of PM is that meter cannot be easily reduced to phonology; this corroborates the points made above

To sum up: according to the view defended here, Tarlinskaja (1989) is right in saying that "verse has its own conventional rules and specific units. In some ways, these correspond to, but do not equate with, language rules and language and speech units" (p. 125).

### 7.4 The dual layering of meter and its consequences for historical metrics

One of the most intriguing aspects of poetic rhythm is its apparent existence on two levels: in the first place, there are the variable (but regimented) instantiations of a
meter as composed texts, and in the second, the semi-independent conventions by which the variable textual variants are rhythmically performed. It is clear that in some cases the textual regularities only make sense when performance conventions, such as line-medial rests, are taken into account (e.g., Schuh 2011); but generative metrics has begun to acknowledge this only relatively recently (e.g., Hayes and Kaun 1996; Kiparsky 2010). In other cases, as a number of recent studies have shown, it appears that linguistic regularities alone can be treated as manifesting a "textual meter", which, however, poet-singers sometimes completely obliterate in performance (e.g., Dell and Elmedlaoui 2008; Hayes and Schuh 2019). This suggests that a poet improvising in such a metrical idiom must be somehow able to simultaneously work with two metrical periodicities, the one controlling the linguistic level and the other its delivery; though it may be the case, as Hayes and Schuh (ibid.) suggest, that the original textual meter has only a diachronic effect on textsetting. Whatever explains the dual metrical layering of some verse forms, it has interesting implications for the study of historical metrical traditions. In particular, assuming that any verse form in principle can exhibit both a textual meter and a musical one, metrical traditions whose performance conventions are largely unknown - as in the case of Greek - can be approached with the apparatus of rhythm research while relying on as few conjectures about performance timing as possible.

### 7.5 Syncopation in Archaic Greek poetry

Quantitative metathesis (i.e., H and L syllables switching places) is a well-known phenomenon in Greek metrics, but occupies a marginal place in it. Kiparsky's (2018) novel theory, however, brings it to the center stage as the rhythmic process that spawned most early Greek verse forms from the same $u r$-source. That source is a hypothetical Indo-European octosyllable, originally proposed by Wilamowitz-Moellendorff (1921) and Meillet (1923), and now reinterpreted by Kiparsky as underlyingly iambic. After its inception in the early 20th century, the idea of deriving various Indo-European historical meters has been borne out by evidence from several languages, including Vedic, Greek and Slavonic (Gasparov 1996, pp. 6-7) and is now generally accepted (e.g., West 2007, p. 46). Kiparsky (ibid.) brings a new piece of evidence to the table by arguing that all early Indo-European meters (and only them, according to him) employ quantitative metathesis, which he interprets as a kind of "variant correspon-
dence" (ibid., p. 98) between an underlying iambic meter and its surface forms-that is, as syncopation. As I discuss, syncopation is also evidenced in some sub-Saharan quantitative metrical traditions of Africa, which somewhat weakens its cause for the IE proto-meter theory. Nevertheless, Kiparsky's proposal serves as an interesting basis for investigating the metrical forms of early Greek lyric from a completely new perspective.

I examined the syllabo-quantitative Aeolic verses of Sappho and Alcaeus based on the assumptions of the syncopation theory. Kiparsky (ibid.) offers syncopation-based analyses of the basic sub-patterns (i.e., cola) that these verses are partly made of, but does not consider the so-called composite and dactylically expanded patterns that Sappho and Alcaeus also use. As I have argued, all of Sappho and Alcaeus' surviving verse can be analyzed as having syncopated rhythms under Kiparsky's theory, so far as it admits two revisions: 1) L syllables can in Aeolic verse sometimes be exceptionally mapped to strong positions (as is also the case of some Vedic meters); and 2) the underlying meter of some verse forms is trochaic instead of iambic (as also paralleled by Vedic). The trochaic analysis of dactylically expanded patterns is, interestingly, supported by the way in which they are composited with other patterns: both Alcaeus and Sappho, as I have tried to demonstrate, combine them with such other patterns that the entire verse maps straightforwardly to a trochaic grid structure, but implausibly to an iambic one. Future work could expand on these findings by further investigating the statistical patterning of Sappho and Alcaeus' verse, including the distribution of subcategorical syllable weight. Such work could benefit from the baseline-prior Maxent models that the current study has introduced; but the task is not without difficulties due to the paucity of surviving texts from this tradition.

### 7.6 Maxent for Greek metrics

Statistics has been used in metrics for problems of chronology and authorship since the late 19th century, but it is most closely associated with 20th century Russian scholarship (e.g., Bailey 1979; Tarlinskaja 1989). The Russian linguistic-statistical methodology (as it is sometimes called) focused on empirical investigations of Russian and Germanic languages and inductive reasonings thereof (Küper 1995). It is interesting to note that though generative metrics owed its two core ideas to the Russian school-the strictly linguistic view of meter and the sharp meter-rhythm dichotomy-it at first wholly ignored its highly developed statistical methods. Instead, early gener-
ative metrics was deductive in orientation and theory-focused; as Brogan (1993) puts it, "the Anglo-American critics pursued theory without facts, the Slavic scholars facts without theory" (p. 779, quoted in Küper 1995).

In recent years, there has been a shift in generative metrics (and generative linguistics in general), where an increasing number of researchers have started to pay more attention to the value of data. Instead of giving rationalizing or "satisfying accounts" of linguistic phenomena, scholars have turned to devising models that can make correct predictions of the data (Hayes 2019). The shift has been in part motivated by the increasing awareness of the gradient nature of many linguistic and metrical rules; and "grammaticalness", acceptability, metricality and metrical complexity are now understood as being matters of degree (as first emphasized in a metrical context by Youmans 1983). Generative metrics has always strived for falsifiable, economic and explicit formal analyses of the intuitive knowledge of fluent participants in a metrical tradition, but until recently the field has lacked a methodology to validate the analyses against large-scale data. A starting point for such an approach, however, was already present in the first generative work on meter by Halle and Keyser (1966), who used a "complexity metric" to approximate the well-formedness intuitions of poets using rules relating to corpus frequency. Hayes (2013) reformulates the same idea in terms of a "frequency hypothesis", according to which line type frequency is inversely related to metrical complexity; and if metrical complexity is analyzed in terms of rules or constraints, the violations of the latter can be used as a proxy to analyze metrical well-formedness. The twist is to turn such a "metrical grammar" into a statistical model that can be used to predict the probabilities of different line types (represented in a metrically relevant form, such as patterns of heavy and light syllables) in some metrical corpus. In (Bayesian) probabilistic terms, such a model represents a quantification of the degree of our rational belief that the poet would choose a given pattern for a verse type (e.g., Jaynes 2003).

Such an approach has a number of desiderata. One is a set of "candidates" whose total probability is 1 , that is, a list of all conceivable line types that the poet might use. Second, the grammar should be formulated in such a way that allows for its ingredients to be used as predictors; the current study, following previous work, has coded them as violable constraints that can be given arbitrary weights. Third, a learning algorithm is required such that it can find the best possible weights for the constraints-weights that can model the data as accurately as possible without making any assumptions
about the data (besides the information provided to it, that is). Maximum entropy modeling (a.k.a. Maxent) is a statistical method that satisfies these requirements by mathematical proof (e.g., Della Pietra et al. 1997). In linguistics, Maxent has become popular in theoretical phonology as a stochastic version of constraint-based models in the intellectual tradition of Optimality theory and Harmonic grammars (e.g., Goldwater and Johnson 2003), and it has also been sporadically used in metrics (e.g., Hayes and Moore-Cantwell 2011; Hayes et al. 2012).

As Tarlinskaja (1989, p. 123) points out, metrical analysis can distinguish different abstractions from metrical corpora. One can analyze, for instance, the style of a single author, or an entire metrical genre in a cultural community. In the Maxent analyses presented in this dissertation, I chose to disregard the differences between authors and concentrated on four distinct metrical forms that appear in Archaic and Classical Greek literature, treating, for instance, Archaic and tragic iambic trimeters as a single dataset. Furthermore, this dissertation has focused exclusively on the distribution of categorical syllable weight, to the exclusion of many fundamental issues such as word boundary distribution and gradient syllable weight (Ryan 2011a). With larger data samples and more detailed metrical annotations, it would be feasible to compare the metrical idioms of different authors (as Hayes et al. 2012, did for Milton and Shakespeare), or even that of individual poetic works; both interesting avenues for future research. In such an approach, it would be possible to characterize what the poets themselves accepted as metrical in a more detailed manner than has been possible in this study.

Two types of Maxent models were devised for each analyzed meter: first, a simple model based on the naive assumption that every possible line type is a priori equally likely, and a complementary "baseline" model, which used bigram-based language models to take into account the prior probability of each pattern as determined by the statistical tendencies of Greek. In previous research, language models have been extensively used in the Russian school of metrics (e.g., Gasparov and Tarlinskaja 1987) but in contemporary generative metrics only sporadically (Biggs 1996; Hayes and Moore-Cantwell 2011; Blumenfeld 2015). The method introduced here is novel: whereas the just cited previous studies have used the chi-squared or Fisher's exact test to compare prose-generated baseline frequencies of some phenomenon with its true frequencies collected from verses, my approach incorporates the baselines directly in the model's learning algorithm as priors for the constraint weights. The main advantage of this method, as compared to the previous approaches, is that it allows the constraints
to interact with each other in the model while they try to satisfy the a priori preferred baseline weights. Arguably, such a model can yield more realistic analyses than those focusing on just one phenomenon piecemeal. In a future study, Maxent-incorporated language models could be used to shed light on more intricate metrical phenomena in Greek poetry such as bridges and caesuras (Devine and Stephens 1984).

The main purpose of the models was to see if the chosen meters-trochaic tetrameter, iambic trimeter (regular and comic variants) and anapestic dimeter-could be plausibly described in terms of metrical grids and a small number of natural rhythmic constraints. In each case, a metrical grid was first devised based on descriptive generalizations of the data under the basic assumption that in these meters, the onsets of heavy syllables normally correspond to strong positions in the grid. The meterphonology relationship was then established in terms of correspondence constraints. In the case of trochaic tetrameters and non-comic iambic trimeters, the data was compatible with a grid with two layers of metrical prominence (here termed strong and superstrong), intriguingly resembling a completely unrelated West Chadic quantitative meter, the Hausa rajaz, which is based on a similar hierarchic metrical pattern (Hayes and Schuh 2019). Although some of the so-called anceps positions, which were here assumed to correspond to weak grid positions, have heavy syllables more often than light ones, the baseline models indicated that this may be a reflex of the Greek language instead of an active preference of the poets, corroborating the periodic analysis. As concerns the comic iambic trimeter and the anapestic dimeter, the results were more mixed. The comic variant of the trimeter, as is well known, is much freer than the non-comic variant, even showing a slight preference for arrhythmicity as against the baseline probabilities of each rhythmic pattern. However, the meter still observes rhythmic constraints near the end of the line and clearly avoids what Greek poets appear to have generally considered rhythmically most disruptive: long stretches of light syllables. Anapestic dimeters, which are now notoriously chaotic due to Golston and Riad's 2000 "classic" (Van Oostendorp 2017) article, were here shown to be far from completely disorganized, albeit not as evidently rhythmically "rising" as they have been traditionally understood. Specifically, it was demonstrated that though the unigram propensities of H and LL in the eight positions of anapestic dimeter unambiguously support an analysis in terms of a dipodic rising rhythm, a Maxent-based analysis reveals this to be a side effect of syntagmatic tendencies, most importantly the avoidance - again - of long strings of Ls. Nevertheless, anapests tend to get more
regular near the ends of metra and periods, which suggests (by the principle of final strictness) that the preferred clausulaic rhythm—namely, the "rising" LLH—was in some sense considered basic in this metrical genre.

Interestingly, the kind of "hierarchy of intersecting periodicities" (Prince 1983, p. 20) that characterizes (as per the current study) some Greek meters was not unknown in ancient theorizing about rhythm. Hierarchic patterns of strong and weak beats were discussed by Aristoxenus in terms of "compound feet" (podés súnthetoi; Elements of Rhythm 19; 26), which also Plato mentions in passing (Republic 400b). Such feet are recursive in the sense that they contain other feet, each with its own arsis and thesis (i.e., upbeat and downbeat), resembling modern ideas about the hierarchical organization of rhythm (Marchetti 2009, p. 148) and lending some credence to the rhythmic portraits of iambic and trochaic metra offered here. Hierarchic rhythms are also evidenced in the musical notation of some Greek musical fragments (e.g., the so-called Song of Seikilos; Pöhlmann and West 2001, p. 88), but they are considerably later than the materials analyzed here.

Finally, it should be noted that statistics is not an end-all for finding answers to metrical questions. As Bailey (1979) says, "the linguistic-statistical method does not and cannot try to answer more than a few specific questions about poetry" (p. 259). The metrical analyses offered in this dissertation have been very limited in scope, and it cannot be ruled out that different results could have been obtained with a more detailed or differently coded dataset. In addition, the approach taken here has been mostly exploratory in nature (Burnham and Anderson 2002, p. 19), in the sense that it has relied on a largely subjective strategy of seeking candidate models based on how well they seem a priori to fit the data. This leaves it open whether even the relatively "best" models (as estimated by AIC) are good approximations to truth, since many other models have been left out of consideration. Nevertheless, the Maxent method of metrical analysis is an improvement over more traditional statistical approaches (such as the chi-squared tests employed extensively by Devine and Stephens 1984) in that it facilitates gauging the reality of apparent metrical constraints within a system of constraints where their effects may interact or depend on one another. Furthermore, if Maxent models are coupled with a principled and structured set of constraints-as I have tried to do here - they invite consideration of their typological implications, an area where this study could be expanded on.

## Bibliography

Abritta, Alejandro. 2015. "On the Role of Accent in Ancient Greek Poetry: Pitch Patterns in the Homeric Hexameter." Quaderni Urbinati di Cultura Classica 111 (3): 11-27.

Adams, Charles Darwin. 1917. "Demosthenes' Avoidance of Breves." Classical Philology 12:271.

Adams, Matthew E. 2011. "Poetic Correspondence and the Cynghanedd Meter." Stanford University.

Adams, Stephen. 1997. Poetic Designs: An Introduction to Meters, Verse Forms, and Figures of Speech. Ontario: Broadview Press.

Agresti, Alan. 2007. An Introduction to Categorical Data Analysis. Hoboken, NJ: Wiley.
Akaike, Hirotogu. 1973. "Information Theory as an Extension of the Maximum Likelihood Principle." In Second International Symposium on Information Theory. Edited by Boris N. Petrov and Frigyes Csaki. Budapest: Akadémiai Kiadó.
—_. 1981. "Likelihood of a Model and Information Criteria." Journal of Econometrics 16:3-14.
1983. "Information Measures and Model Selection." International Statistical Institute 44:277-291.

Allen, William Sidney. 1973. Accent and Rhythm: Prosodic Features of Latin and Greek: A Study in Theory and Reconstruction. Vol. 12. Cambridge Studies in Linguistics. Cambridge: Cambridge University Press.
__. 1987. Vox Graeca: The Pronunciation of Classical Greek. Cambridge: Cambridge University Press.

Arnold, Edward Vernon. 1905. Vedic Metre in Its Historical Development. Cambridge: Cambridge University Press.

Arrazola, Varun D. C. 2021. "Deviants Are Detected Faster at the End of Verse-Like Sound Sequences." Frontiers in Psychology 12:3527.

Asch, Solomon E. 1946. "Max Wertheimer's Contribution to Psychology." Social Research 13:81-102.

Attridge, Derek. 1996. Poetic Rhythm: An Introduction. Cambridge: Cambridge University Press.
__. 2016. "Rhythm." Edited by Roland Greene and Stephen Cushman. The Princeton Handbook of Poetic Terms: Third Edition (Princeton), 299-303.

Bailey, James. 1975. Toward a Statistical Analysis of English Verse: The Iambic Tetrameter of Ten Poets. Lisse, Netherlands: The Peter De Ridder Press.
__ 1979. "The Russian Linguistic-Statistical Method for Studying Poetic Rhythm: A Review Article." The Slavic and East European Journal 23 (2): 251-261.

Baker, Brett. 2014. "Word Structure in Australian Languages." In The Languages and Linguistics of Australia: A Comprehensive Guide, edited by Harold Koch and Rachel Nordlinger, 139-213. Berlin: De Gruyter.

Banti, Giorgio, and Francesco Giannattasio. 1996. "Music and Metre in Somali Poetry." African Languages and Cultures. Supplement, no. 3, 83-127.
—_ 2005. "Poetry." In A Companion to Linguistic Anthropology, edited by Alessandro Duranti, 290-320. Malden, MA: Wiley-Blackwell.

Barker, Andrew. 1991. "Review of Elementa Rhythmica, Aristoxenus." Music छ Letters 72 (1): 71-74.

Barnes, Harry R. 1986. "The Colometric Structure of Homeric Hexameter." Greek, Roman and Byzantine Studies 27 (2): 125.

Battezzato, Luigi. 2009. "Metre and Music." In The Cambridge Companion to Greek Lyric, edited by Felix Budelmann, 130-146. Cambridge: Cambridge University Press.
. 2018. "The Structure of Sappho's Books: Metre, Page Layout, and the Hellenistic and Roman Poetry Book." Zeitschrift für Papyrologie und Epigraphik 208:124.

Beckman, Mary E., and Jan Edwards. 1987. "The Phonological Domains of Final Lengthening." The Journal of the Acoustical Society of America 81 (S1): S67S67.

Berg, Nils. 1978. "Parergon Metricum: Der Ursprung Des Griechischen Hexameters." Münchener Studien zur Sprachwissenschaft 36:11-36.

Berger, Adam L., Stephen A. Della Pietra, and Vincent J. Della Pietra. 1996. "A Maximum Entropy Approach to Natural Language Processing." Computational Linguistics 22 (1): 39-71.

Bergk, Theodor. 1854. "Über Das Älteste Versmass Der Griechen." Opuscula philologica 2:392-408.

Berwick, Robert C., and Amy S. Weinberg. 1984. The Grammatical Basis of Linguistic Performance. Cambridge, MA: MIT Press.

Biggs, Henry Parkman. 1996. "A Statistical Analysis of the Metrics of the Classic French Decasyllable and the Classic French Alexandrine." PhD diss., UCLA.

Bjorklund, Beth. 1979. "Elements of Poetic Rhythm: Stress, Syllabicity, Sound, and Sense." Poetics 8 (4): 351-365.

Bliss, Alan Joseph. 1958. The Metre of Beowulf. Oxford: Blackwell.

Blumenfeld, Lev. 2004. "Tone-to-Stress and Stress-to-Tone: Ancient Greek Accent Revisited." In Inproceedings, 30:1-12.
__ 2015. "Meter as Faithfulness." Natural Language $\varepsilon^{8}$ Linguistic Theory 33 (1): 79-125.
___ 2016. "End-Weight Effects in Verse and Language." Studia Metrica et Poetica 3 (1): 7-32.

Boeckh, Augustus. 1811. "De Metris Pindari: Liber I." In Pindar. Opera Quae Supersunt. Textum in Genuina Metra Restituit et Ex Fide Librorum Manuscriptorum Doctorumque Coniecturis Recensuit, Annotationem Criticam Scholia Integra Interpretationem Latinam Commentarium Perpetuum et Indices Adiecit Augustus Boeckhius. Tomus I. Leipzig.

Bolton, Thaddeus L. 1894. "Rhythm." American Journal of Psychology 6:145-238.

Boltzmann, Ludwig. 1868. "Studien Über Das Gleichgewicht Der Lebendigen Kraft Zwischen Bewegten Materiellen Punkten." Wiener Berichte 58:517-560.

Box, George E.P., and Gwilym M. Jenkins. 1970. Time Series Analysis: Forecasting and Control. London: Holden-Day.

Brailoiu, Constantin. 1952. "Le Giusto Syllabique. Un Systeme Rythmique Populaire Roumaine." Anuario Musical 8:117-158.

Bregman, Albert S. 1990. Auditory Scene Analysis. Cambridge, MA: MIT Press.

Breiss, Canaan, and Bruce Hayes. 2019. "Phonological Markedness Effects in Sentence Formation." 96 (2): 338-370.

Bridle, John S. 1990. "Probabilistic Interpretation of Feedforward Classification Network Outputs, with Relationships to Statistical Pattern Recognition." In Neurocomputing, edited by Françoise Fogelman Soulié and Jeanny Hérault, 227-236. NATO ASI Series. Berlin: Springer.

Brochard, Renaud, Donna Abecasis, Doug Potter, Richard Ragot, and Carolyn Drake. 2003. "The "ticktock" of Our Internal Clock: Direct Brain Evidence of Subjective Accents in Isochronous Sequences." Psychological Science 14 (4): 362-366.

Brogan, T. V. F. 1993. "Meter." Edited by Alex Preminger and T. V. F. Brogan. The New Princeton Encyclopedia of Poetry and Poetics (Princeton), 763-783.

Brogan, T.V.F., Wolfgang Bernhard Fleischmann, Tyler Hoffman, and Thomas Carper. 2012a. "Metrici and Rhythmici." Edited by Steven Cushman, Clare Cavanagh, Jahan Ramazani, and Paul Rouzer. The Princeton Encyclopedia of Poetry and Poetics (Princeton), 878.
___ 2012b. "Performance." Edited by Steven Cushman, Clare Cavanagh, Jahan Ramazani, and Paul Rouzer. The Princeton Encyclopedia of Poetry and Poetics (Princeton), 1016-1020.

Bröggelwirth, Jörg. 2006. "Ein Rhythmisch-Prosodisches Modell Lyrischen Sprechstils." PhD diss., Universität Bonn.

Bross, Christoph, Dieter C. Gunkel, and Kevin M. Ryan. 2015. "The Colometry of Tocharian 4x15-Syllable Verse." In Tocharian Texts in Context, edited by Melanie Malzahn, Michaël Peyrot, Hannes Fellner, and Theresa-Susanna Illés, 15-28. Bremen: Hempen.

Brown, Anita. 2018. "Quantitative Metathesis in Ancient Greek." Swarthmore College. Dept. of Linguistics.

Brown, Edward J. 1983. "Roman Osipovich Jakobson 1896-1982 the Unity of His Thought on Verbal Art." The Russian Review 42 (1): 91-99.

Budelmann, Felix. 2009. "Introducing Greek Lyric." In The Cambridge Companion to Greek Lyric, edited by Felix Budelmann, 1-18. Cambridge: Cambridge University Press.

Burling, Robbins. 1966. "The Metrics of Children's Verse: A Cross-Linguistic Study." American Anthropologist 68 (6): 1418-1441.

Burnham, Kenneth P., and David R. Anderson. 2002. Model Selection and Multi-Model Inference. Second. New York, NY: Springer.
_-. 2004. "Multimodel Inference: Understanding AIC and BIC in Model Selection." Sociological Methods \& Research 33 (2): 261-304.

Cambouropoulos, Emilios. 2001. "The Local Boundary Detection Model and Its Application in the Study of Expressive Timing." Proceedings of the International Computer Music Conference, 17-22.

Carroll, Benjamin H. 1993. "Metrical Resolution in Old English." The Journal of English and Germanic Philology 92 (2): 167-178.

Červenka, Miroslav. 1984. "Rhythmical Impulse: Notes and Commentaries." Wiener Slawistischer Almanach 14:23-53.

Chatman, Seymour. 1960. "Comparing Metrical Styles." In Style in Language, edited by Thomas A. Sebeok, 149-173. Boston: MIT Press.

Chen, Matthew Y. 1979. "Metrical Structure: Evidence from Chinese Poetry." Linguistic Inquiry 10 (3): 371-420.

Chen, Stanley F., and Ronald Rosenfeld. 1999. "A Gaussian Prior for Smoothing Maximum Entropy Models." Computer Science Department, Carnegie Mellon University.
——_ 2000. "A Survey of Smoothing Techniques for ME Models." IEEE Transactions on Speech and Audio Processing 8 (1): 37-50.

Chong, Edwin K.P., and Stanislaw H. Żak. 2013. An Introduction to Optimization. Hoboken, NJ: Wiley.

Clarke, Eric F. 1999. "Rhythm and Timing in Music." In The Psychology of Music, Second, edited by Diana Deutsch, 473-500. San Diego, CA: Academic Press.

Clayton, Martin. 2010. Time in Indian Music: Rhythm, Metre, and Form in North Indian Rāg Performance. Oxford: Oxford University Press.

Clements, George N. 1990. "The Role of the Sonority Cycle in Core Syllabification." In Papers in Laboratory Phonology: Volume 1: Between the Grammar and Physics of Speech, edited by John Kingston and Mary E. Beckman, 1:283-333. Papers in Laboratory Phonology. Cambridge: Cambridge University Press.

Cole, Deborah, and Mizuki Miyashita. 2006. "The Function of Pauses in Metrical Studies: Acoustic Evidence from Japanese Verse." In Formal Approaches to Poetry: Recent Developments in Metrics, edited by B. Elan Dresher and Nila Friedberg, 173-192. Berlin: Mouton de Gruyter.

Cole, Thomas. 1988. Epiploke: Rhythmical Continuity and Poetic Structure in Greek Lyric. Cambridge, MA: Harvard University Press.

Consbruch, Maximilianus, ed. 1906. Hephaestionis Enchiridion, Cum Commentariis Veteribus Edidit. Leipzig: Teubner.

Conser, Anna. 2017. Greek_scansion: Tools for Analyzing the Prosody of Ancient Greek Poetry and Prose. Accessed January 10, 2020. https:// github.com / aconser / greek_scansion.

Cooper, G. Burns. 2012. "Free Verse." Edited by Steven Cushman, Clare Cavanagh, Jahan Ramazani, and Paul Rouzer. The Princeton Encyclopedia of Poetry and Poetics (Princeton), 522-525.

Cooper, Grosvenor, and Leonard B. Meyer. 1971. The Rhythmic Structure of Music. Chicago: University of Chicago Press.

Crane (ed.), Gregory R. 2020. Perseus Digital Library. Tufts University. Accessed January 10, 2020. https://www.perseus.tufts.edu.

Daland, Robert. 2015. "Long Words in Maximum Entropy Phonotactic Grammars." Phonology, no. 32, 353-83.

Dale, Amy Marjorie. 1968. The Lyric Metres of Greek Drama. Second. Cambridge.
De Lacy, Paul. 2002. "The Formal Expression of Markedness." PhD diss., University of Massachusetts.
deCastro-Arrazola, Varun. 2018. "Typological Tendencies in Verse and Their Cognitive Grounding." PhD diss., Netherlands Graduate School of Linguistics.

Deliège, Irene. 1987. "Grouping Conditions in Listening to Music: An Approach to Lerdahl \& Jackendoff's Grouping Preference Rules." Music Perception 4 (4): 325359.

Dell, François. 2011. "Singing in Tashlhiyt Berber, a Language That Allows VowelLess Syllables." In Handbook of the Syllable, edited by Charles E. Cairns and Eric Raimy, 173-193. Leiden: Brill.
__ 2015. "Text-to-Tune Alignment and Lineation in Traditional French Songs." Text and tune: On the association of music and lyrics in sung verse. Frankfurt: Peter Lang, 183-234.

Dell, François, and Mohamed Elmedlaoui. 2008. Poetic Meter and Musical Form in Tashlhiyt Berber Songs. Berber Studies 19. Cologne: Rüdiger Köppe.

Della Pietra, Stephen, Vincent Della Pietra, and John Lafferty. 1997. "Inducing Features of Random Fields." IEEE transactions on pattern analysis and machine intelligence 19 (4): 380-393.

Deo, Ashwini. 2007. "The Metrical Organization of Classical Sanskrit Verse." Journal of linguistics 43 (1): 63-114.

Deo, Ashwini, and Paul Kiparsky. 2011. "Poetries in Contact: Arabic, Persian, and Urdu." In Frontiers of Comparative Metrics, edited by Maria-Kristiina Lotman, 147-73. Bern, New york: Peter Lang.

Devine, Andrew M., and Laurence D. Stephens. 1975. "Anceps." Greek, Roman and Byzantine Studies 16 (2): 197-215.
—_. 1976. "The Homeric Hexameter and a Basic Principle of Metrical Theory." Classical Philology 71 (2): 141-163.
__. 1984. Language and Metre: Resolution, Porson's Bridge, and Their Prosodic Basis. Chico, CA: Scholars Press.
—_. 1994. The Prosody of Greek Speech. New York: Oxford University Press.

Downing, Laura J. 2006. Canonical Forms in Prosodic Morphology. 12. Oxford University Press.

Drake, Carolyn. 1993. "Reproduction of Musical Rhythms by Children, Adult Musicians, and Adult Nonmusicians." Perception $\xi^{3}$ Psychophysics 53 (1): 25-33.

Drew-Bear, Thomas. 1968. "The Trochaic Tetrameter in Greek Tragedy." The American Journal of Philology 89 (4): 385-405.

Dudík, Miroslav, Steven J. Phillips, and Robert E. Schapire. 2004. "Performance Guarantees for Regularized Maximum Entropy Density Estimation." In Learning Theory, edited by John Shawe-Taylor and Yoram Singer, 3120:472-486. Lecture Notes in Computer Science. Berlin: Springer.
__. 2007. "Maximum Entropy Density Estimation with Generalized Regularization and an Application to Species Distribution Modeling." Journal of Machine Learning Research 8 (44): 1217-1260.

Edwards, Jan, Mary E. Beckman, and Janet Fletcher. 1991. "The Articulatory Kinematics of Final Lengthening." The Journal of the Acoustical Society of America 89 (1): 369-382.

Fabb, Nigel. 2002. Language and Literary Structure: The Linguistic Analysis of Form in Verse and Narrative. Cambridge: Cambridge University Press.
__ 2014. "The Verse-Line as a Whole Unit in Working Memory, Ease of Processing, and the Aesthetic Effects of Form." Royal Institute of Philosophy Supplement 75:29-50.
—_ 2017. "Linguistics and Literature." In The Handbook of Linguistics, Second, edited by Mark Aronoff and Janie Rees-Miller, 463-477. Hoboken, NJ: WileyBlackwell.

Fabb, Nigel, and Morris Halle. 2008. Meter in Poetry: A New Theory. Cambridge: Cambridge University Press.

Fant, Gunnar, Anita Kruckenberg, and Lennart Nord. 1991. "Stress Patterns and Rhythm in the Reading of Prose and Poetry with Analogies to Music Performance." In Music, Language, Speech and Brain: Proceedings of an International Symposium at the Wenner-Gren Center, Stockholm, 5-8 September 1990, edited by Johan Sundberg, Lennart Nord, and Rolf Carlson, 380-407. London: Macmillan Education UK.

Féry, Caroline. 2017. Intonation and Prosodic Structure. Key Topics in Phonology. Cambridge: Cambridge University Press.

Finglass, Patrick J. 2012. "The Textual Transmission of Sophocles' Dramas." In A Companion to Sophocles, edited by Kirk Ormand, 7-24. Malden, MA: Wiley-Blackwell.

Fischer, Jack L. 1959. "Meter in Eastern Carolinian Oral Literature." The Journal of American Folklore 72 (283): 47-52.

Fraisse, Paul. 1982. "Rhythm and Tempo." In The Psychology of Music, edited by Diana Deutsch, 149-180. New York: Academic Press.

Frost, Jim. 2019. Regression Analysis: An Intuitive Guide for Using and Interpreting Linear Models. State College, PA: Statistics by Jim Publishing.

Gasparov, M. L., and Marina Tarlinskaja. 1987. "A Probability Model of Verse (English, Latin, French, Italian, Spanish, Portuguese)." Style 21 (3): 322-358.

Gasparov, Mikhail Leonovich. 1996. A History of European Versification. Oxford: Oxford University Press.

Gentili, Bruno. 1958. Anacreon. Rome: Edizioni dell' Ateneo.

Gentili, Bruno, and Liana Lomiento. 2003. Metrica e Ritmica: Storia Delle Forme Poetiche Nella Grecia Antica. Città di castello: Mondadori Università.
—_ 2009. "Observations on Hephaestion Addressed to His Cultured Despisers." Quaderni Urbinati di Cultura Classica 91 (1): 123-128.

Gerber, Douglas. 1999. Greek Iambic Poetry: From the Seventh to the Fifth Centuries BC, Edited and Translated by Douglas E. Gerber. The Loeb Classical Library 259. Cambridge, MA: Harvard University Press.

Ghomeshi, Jila, Ray Jackendoff, Nicole Rosen, and Kevin Russell. 2004. "Contrastive Focus Reduplication in English (The Salad-Salad Paper)." Natural Language $\xi^{\circ}$ Linguistic Theory 22 (2): 307-357.

Gibbs, J. Willard. 1902. Elementary Principles in Statistical Mechanics. New York, NY: Scribner's sons.

Giuli, Paola. 1987. "Samuel Taylor Coleridge and Roman Jakobson on the Music of Poetry." Master's thesis, American University.

Goldwater, Sharon, and Mark Johnson. 2003. "Learning OT Constraint Rankings Using a Maximum Entropy Model." In Proceedings of the Stockholm Workshop on Variation within Optimality Theory, 111-120.

Golston, Chris. 1990. "Floating H (and L*) Tones in Ancient Greek." In Arizona Phonology Conference, 3:66-82.
__ 1996. "Direct Optimality Theory: Representation as Pure Markedness." Language, 713-748.
——. 1998. "Constraint-Based Metrics." Natural Language \& Linguistic Theory 16:719-770.
—__ 2021. "A Quantitative Tetrameter for Proto-Indo-European." In Synchrony and Diachrony of Ancient Greek: Language, Linguistics and Philology, edited by George K. Giannakis, Luz Conti, Jesús de la Villa, and Raquel Fornieles, 439-461. Trends in Classics - Supplementary Volumes 112. Berlin: Walter de Gruyter.

Golston, Chris, and Tomas Riad. 1994. Constraint Based Metrics. Paper Presented at the 1994 Trilateral Phonology Weekend, Santa Cruz.
—_ 1995. Direct Metrics. Paper Presented at LSA. Boston.
___ 1997. "The Phonology of Classical Arabic Meter." Linguistics 35:111-132.
__ 2000. "The Phonology of Classical Greek Meter." Linguistics 38:99-167.
2005. "The Phonology of Greek Lyric Meter." Journal of linguistics 41 (1): 77-115.

Gordon, Matthew Kelly. 2007. Syllable Weight: Phonetics, Phonology, Typology. New York: Routledge.
__ 2017. "Syllable Weight: A Typological and Theoretical Overview." In Syllable Weight in African Languages, edited by Paul Newman, 27-48. Amsterdam: John Benjamins.

Greenberg, Joseph H. 1949. "Hausa Verse Prosody." Journal of the American Oriental Society 69:125-135.

Griffith, Ralph Thomas Hotchkin. 1889. Hymns of the Rigveda. Kotagiri (Nilgiri).
Gunkel, Dieter C. 2014. "Accentuation." Encyclopedia of Ancient Greek Language and Linguistics 1:7-12.

Gunkel, Dieter C., and Kevin M. Ryan. 2011. "Hiatus Avoidance and Metrification in the Rigveda." In Inproceedings, 53-68. Bremen.

Guyon, Isabelle, Amir Saffari, Gideon Dror, and Gavin Cawley. 2010. "Model Selection: Beyond the Bayesian/Frequentist Divide." Journal of Machine Learning Research 11:61-87.

Haegens, Saskia, and Elana Zion Golumbic. 2018. "Rhythmic Facilitation of Sensory Processing: A Critical Review." Neuroscience E Biobehavioral Reviews 86:150-165.

Hagel, Stefan. 2008. "Ancient Greek Rhythm: The Bellermann Exercises." Quaderni Urbinati di Cultura Classica 88 (1): 125-138.

Halle, Morris, and Samuel Jay Keyser. 1966. "Chaucer and the Study of Prosody." College English 28 (3): 187-219.
——. 1971a. English Stress: Its Form, Its Growth, and Its Role in Verse. New York: Harper and Row.
—_. 1971b. "Illustration and Defense of a Theory of the Iambic Pentameter." College English 33 (2): 154-176.

Halle, Morris, and Jean-Roger Vergnaud. 1987. An Essay on Stress. Current Studies in Linguistics 15. Cambridge, MA: MIT Press.

Halporn, James W. 1967. "Nietzsche: On the Theory of Quantitative Rhythm." Arion: A Journal of Humanities and the Classics 6 (2): 233-243.

Halporn, James W., Martin Ostwald, and Thomas G. Rosenmeyer. 1963. The Meters of Greek and Latin Poetry. London: Methuen \& Co.

Hammond, Michael. 2012. "The Phonology of Welsh Cynghanedd." Lingua 122 (4): 386-408.

Hanson, Kristin. 1992. "Resolution in Modern Meters." PhD diss., Stanford University.

Hanson, Kristin, and Paul Kiparsky. 1996. "A Parametric Theory of Poetic Meter." Language 72 (2): 287-335.

Harnad, Stevan. 2017. "To Cognize Is to Categorize: Cognition Is Categorization." In Handbook of Categorization in Cognitive Science, Second, edited by Henri Cohen and Claire Lefebvre, 21-54. San Diego: Elsevier.

Hasty, Christopher. 1997. Meter as Rhythm. Oxford: Oxford University Press.

Haug, Dag, and Eirik Welo. 2001. "The Proto-Hexameter Hypothesis: Perspectives for Further Research." Symbolae Osloenses 76 (1): 130-136.

Hay, Jessica S. F., and Randy L. Diehl. 2007. "Perception of Rhythmic Grouping: Testing the Iambic/Trochaic Law." Perception E Psychophysics 69 (1): 113-122.

Hayes, Bruce. 1979. "The Rhythmic Structure of Persian Verse." Edebiyat 4:193-242.
——. 1983. "A Grid-Based Theory of English Meter." Linguistic Inquiry 14 (3): 357393.
__. 1984. "The Phonology of Rhythm in English." Linguistic Inquiry 15:33-74.
1985. "Iambic and Trochaic Rhythm in Stress Rules." In Proceedings of the Eleventh Annual Meeting of the Berkeley Linguistics Society, edited by Mary Niepokuj, Mary van Clay, Vassiliki Nikiforidou, and Deborah Feder, 429-446. Berkeley.
1988. "Metrics and Phonological Theory." In Linguistics: The Cambridge Survey, edited by Frederick J. Newmeyer, vol. 2, Linguistic theory: Extensions and implications, 220-249. Cambridge: Cambridge University Press.
—_ 1989a. "Compensatory Lengthening in Moraic Phonology." Linguistic inquiry 20 (2): 253-306.

1989b. "The Prosodic Hierarchy in Meter." In Phonetics and Phonology, edited by Paul Kiparsky and Gilbert Youmans, vol. 1: Rhythm and Meter, 201-260. San Diego, CA: Academic Press.
1995. Metrical Stress Theory. Chicago: Chicago University Press.
—_ 2009. "Faithfulness and Componentiality in Metrics." In The Nature of the Word: Studies in Honor of Paul Kiparsky, edited by Sharon Inkelas and Kristin Hanson, 113-148. Cambridge, MA: MIT Press.
2010. "Review of: Meter in Poetry." Lingua 120:2515-2521.
2013. Milton, Maxent, and the Russian Method. Paper Delivered at M90 Workshop on Stress and Meter. MIT.
_-. 2018. Some Remarks on MaxEnt Grammars. Talk given at the Workshop at Stanford University, "Analyzing Typological Structure: From Categorical to Probabilistic Phonology".
2019. Class 1, 1/9/17: Goals; Maxent I. Lecture. UCLA.

Forthcoming. "Deriving the Wug-shaped Curve: A Criterion for Assessing Formal Theories of Linguistic Variation." Annual Review of Linguistics.

Hayes, Bruce, and Abigail Kaun. 1996. "The Role of Phonological Phrasing in Sung and Chanted Verse." Linguistic Review 13:243-303.

Hayes, Bruce, and Aditi Lahiri. 1991. "Bengali Intonational Phonology." Natural language 8 linguistic theory 9 (1): 47-96.

Hayes, Bruce, and Margaret MacEachern. 1998. "Quatrain Form in English Folk Verse." Language 74 (3): 473-507.

Hayes, Bruce, and Claire Moore-Cantwell. 2011. "Gerard Manley Hopkins' Sprung Rhythm: Corpus Study and Stochastic Grammar." Phonology 28:235-282.

Hayes, Bruce, and Russell G. Schuh. 2015. Class 6, 3/15/15: Hierarchy in the Metrical Pattern. Lecture.
__ 2019. "Metrical Structure and Sung Rhythm of the Hausa Rajaz." Language 95 (2): e253-e299.

Hayes, Bruce, and Colin Wilson. 2008. "A Maximum Entropy Model of Phonotactics and Phonotactic Learning." Linguistic inquiry 39 (3): 379-440.

Hayes, Bruce, Colin Wilson, and Anne Shisko. 2012. "Maxent Grammars for the Metrics of Shakespeare and Milton." Language 88 (4): 691-731.

Helsloot, Catharine Josephine. 1995. "Metrical Prosody: A Template-and-Constraint Approach to Phonological Phrasing in Italian. Based on the Poetry of Giuseppe Ungaretti and Eugenio Montale." PhD diss., University of Amsterdam.

Honing, Henkjan. 2012. "Without It No Music: Beat Induction as a Fundamental Musical Trait." Annals of the New York Academy of Sciences 1252 (1): 85-91.
_-. 2013. "Structure and Interpretation of Rhythm in Music." In The Psychology of Music, Third, edited by Diana Deutsch, 369-404. San Diego, CA: Elsevier Academic Press.
_-. 2014. Musical Cognition: A Science of Listening. Translated by Sherry Marx and Susan van der Werff-Woolhouse. New Brunswick, NJ: Transaction Publishers.

Honing, Henkjan, Carel ten Cate, Isabelle Peretz, and Sandra E. Trehub. 2015. "Without It No Music: Cognition, Biology and Evolution of Musicality." Philosophical Transactions of the Royal Society B: Biological Sciences 370 (1664): 20140088.

Huron, David Brian. 2006. Sweet Anticipation: Music and the Psychology of Expectation. Cambridge, MA: MIT press.

Hyman, Larry M. 1985. A Theory of Phonological Weight. Publications in Language Sciences 19. Dordrecht: Foris.
—_. 2018. "Why Underlying Representations?" Journal of Linguistics 54 (3): 591610.

Inkelas, Sharon. 1989. "Prosodic Constituency in the Lexicon'." PhD diss., Stanford University.

Irvine, Ann, and Mark Dredze. 2017. "Harmonic Grammar, Optimality Theory, and Syntax Learnability: An Empirical Exploration of Czech Word Order." arXiv:1702.05793, arXiv: 1702.05793.

Itsumi, Kiichiro. 1982. "The 'Choriambic Dimeter' of Euripides." The Classical Quarterly 32 (1): 59-74.
—__ 1984. "The Glyconic in Tragedy." The Classical Quarterly 34 (1): 66-82.
Iversen, John R., Aniruddh D. Patel, and Kengo Ohgushi. 2008. "Perception of Rhythmic Grouping Depends on Auditory Experience." The Journal of the Acoustical Society of America 124 (4): 2263-2271.

Jackendoff, Ray. 1989. "A Comparison of Rhythmic Structures in Music and Language." In Phonetics and Phonology, edited by Paul Kiparsky and Gilbert Youmans, vol. 1: Rhythm and Meter, 15-44. San Diego, CA: Academic Press.
——. 2007. Language, Consciousness, Culture: Essays on Mental Structure. Cambridge, MA: MIT Press.
2009. "Parallels and Nonparallels between Language and Music." Music Perception: An Interdisciplinary Journal 26 (3): 195-204.
—_ 2011. "What Is the Human Language Faculty? Two Views." Language 87 (3): 586-624.

Jackendoff, Ray, and Fred Lerdahl. 2006. "The Capacity for Music: What Is It, and What's Special about It?" Cognition 100 (1): 33-72.

Jäger, Gerhard, and Anette Rosenbach. 2006. "The Winner Takes It All - Almost: Cumulativity in Grammatical Variation." 44 (5): 937-971.

Jakobson, Roman. 1960. "Closing Statement: Linguistics and Poetics." In Style in Language, edited by Thomas A. Sebeok, 350-377. Boston: MIT Press.
——. 1979. Selected Writings. Edited by Stephen Rudy and Martha Taylor. Vol. 5: On Verse, Its Masters and Explorers. The Hague: Walter de Gruyter.
——. 1985. Verbal Art, Verbal Sign, Verbal Time. Edited by Krystyna Pomorska and Stephen Rudy. Minneapolis, MN: University of Minnesota Press.

Jaynes, Edwin T. 1957. "Information Theory and Statistical Mechanics." Physical review 106 (4): 620-630.
2003. Probability Theory: The Logic of Science. Cambridge: Cambridge university press.

Jesney, Karen, and Anne-Michelle Tessier. 2008. "Gradual Learning and Faithfulness: Consequences of Ranked vs. Weighted Constraints." In Proceedings of the 38th Meeting of the North East Linguistics Society (NELS 38), 1:375-388.

Jespersen, Otto. 1933. "Notes on Metre." In Linguistica: Selected Papers in English, French and German, 249-74. Copenhagen: Levin and Munksgaard.

Johnson, Mark. 2002. "Optimality-Theoretic Lexical Functional Grammar." In The Lexical Basis of Sentence Processing: Formal, Computational and Experimental Issues, edited by Paola Merlo and Suzanne Stevenson, 59-73. Amsterdam: John Benjamins.
. 2013. A Gentle Introduction to Maximum Entropy, Log-Linear, Exponential, Logistic, Harmonic, Boltzmann, Markov Random Fields, Conditional Random Fields, Etc., Models. Slides.

Jones, Mari R. 1976. "Time, Our Lost Dimension: Toward a New Theory of Perception, Attention, and Memory." Psychological Review 83 (5): 323-355.

Jurafsky, Dan, and James H. Martin. 2020. Speech and Language Processing. Third. Draft of December 30, 2020. Accessed February 2, 2021. https://web.stanford. edu/~jurafsky/slp3/.

Kager, René Willibrord Joseph. 1993. "Alternatives to the Iambic-Trochaic Law." Natural Language $\S^{3}$ Linguistic Theory 11 (3): 381-432.
__. 1995. "Consequences of Catalexis." In Leiden in Last: HIL Phonology Papers, edited by Harry Van Der Hulst and Jeroen Maarten van de Weijer, 1:269-298. The Hague: Holland Academic Graphics,
——. 2001. Rhythmic Directionality by Positional Licensing. Handout for Talk at Fifth HIL Phonology Conference (HILP 5). University of Potsdam.
_. 2005. "Rhythmic Licensing Theory : An Extended Typology." Proceedings of the third international conference on phonology, 5-31.
2007. "Feet and Metrical Stress." In The Cambridge Handbook of Phonology, edited by Paul De Lacy, 195-227. Cambridge: Cambridge University Press.

Kahnemuyipour, Arsalan. 2003. "Syntactic Categories and Persian Stress." Natural Language ${ }^{6}$ Linguistic Theory 21 (2): 333-379.

Kaplan, Aaron. 2018. "Positional Licensing, Asymmetric Trade-Offs and Gradient Constraints in Harmonic Grammar." Phonology 35 (2): 247-286.

Katz, Jonah. 2018. "Grouping in Music and Language." lingbuzz/003938.

Kenstowicz, Michael. 1994. Phonology in Generative Grammar. Cambridge, MA: Blackwell.

Kesavan, Hiremagalur Krishnaswamy. 2009. "Jaynes' Maximum Entropy Principle: MaxEnt." Edited by Christodoulos A. Floudas and Panos M. Pardalos. Encyclopedia of optimization, 1779-1782.

Kiparsky, Paul. 1968. "Metrics and Morphophonemics in the Kalevala." In Studies Presented to Roman Jakobson by His Students, 137-148. Cambridge, MA: Slavica.
—_ 1973. "The Role of Linguistics in a Theory of Poetry." Daedalus 102 (3): 231244.
__. 1975. "Stress, Syntax, and Meter." Language 51:576-616.
—_. 1977. "The Rhythmic Structure of English Verse." Linguistic inquiry 8 (2): 189-247.
—_ 1984. "Roman Jakobson and the Grammar of Poetry." In A Tribute to Roman Jakobson 1896-1982, edited by Morris Halle and Paul E. Gray, 27-38. Berlin: Mouton.
__. 1991. "Catalexis." Stanford University and Wissenschaftskolleg zu Berlin.
——. 2003. "Accent, Syllable Structure, and Morphology in Ancient Greek." In Selected Papers from the 15th International Symposium on Theoretical and Applied Linguistics, edited by Elizabeth Mela-Athanasopoulou, 81-106. Thessaloniki: Aristotle University of Thessaloniki.
—_ 2006a. "A Modular Metrics for Folk Verse." In Formal Approaches to Poetry, edited by B. Dresher Elan and Nila Friedberg, 7-49. Berlin: De Gruyter Mouton.

Kiparsky, Paul. 2006b. "Iambic Inversion in Finnish." In A Man of Measure: Festschrift in Honour of Fred Karlsson on His 60th Birthday, edited by Mickael Suominen, Antti Arppe, Anu Airola, Orvokki Heinämäki, Matti Miestamo, Urho Määttä, Jussi Niemi, Kari K. Pitkänen, and Kaius Sinnemäki, 138-148. Turku: The Linguistic Association of Finland.
_-. 2009. "Review of: Meter in Poetry." Language 85 (4): 923-930.
_-. 2010. Meter and Performance. Presentation at LSA Metrics Symposium.
—_. 2018. "Indo-European Origins of the Greek Hexameter." In Sprache Und Metrik, edited by Dieter C. Gunkel and Olav Hackstein, 77-128. Leiden: Brill.
2019. "Stress, Meter, and Text-setting." In The Oxford Handbook of Language Prosody, edited by Aoju Chen and Carlos Gussenhoven. Oxford: Oxford University Press.
——. 2020. "Metered Verse." Annual Review of Linguistics 6:25-44.

Klapp, Stuart T., Martin D. Hill, John G. Tyler, Zeke E. Martin, Richard J. Jagacinski, and Mari Riess Jones. 1985. "On Marching to Two Different Drummers: Perceptual Aspects of the Difficulties." Journal of Experimental Psychology: Human Perception and Performance 11 (6): 814-827.

Klein, Dan, and Chris Manning. 2003. Maxent Models, Conditional Estim Ation, and Optimization. Tutorial.

Klein, Thomas B. 2000. Umlaut in Optimality Theory: A Comparative Analysis of German and Chamorro. Tübingen: Niemeyer.
2003. "Syllable Structure and Lexical Markedness in Creole Morphophonology: Determiner Allomorphy in Haitian and Elsewhere." In The Phonology and Morphology of Creole Languages, edited by Ingo Plag, 209-228. Tübingen: Niemeyer.

Kolmogorov, Andrei M. 1968. "Primer Izucheniia Metra i Ego Ritmicheskikh Variantov." In Teoriia Stikha, edited by V. M. Zhirmunsky and et al. Leningrad: Nauka.

Korzeniewski, Dietmar. 1968. Griechische Metrik. Darmstadt: Wissenschaftliche Buchgesellschaft.

Kotz, S. A., A. Ravignani, and W. T. Fitch. 2018. "The Evolution of Rhythm Processing." Trends in Cognitive Sciences 22, no. 10 (October): 896-910.

Kozasa, Tomoko. 1997. "Rhythm or Meter: Moraic Tetrameter in Japanese Poetry." California State University, Fresno.

Krämer, Martin. 2012. Underlying Representations. Cambridge: Cambridge University Press.

Kruckenberg, Anita, and Gunnar Fant. 1993. "Iambic versus Trochaic Patterns in Poetry Reading." In Prosody, vol. 6. 123-135. Stockholm.

Krumhansl, Carol L. 2000. "Rhythm and Pitch in Music Cognition." Psychological Bulletin 126 (1): 159-179.

Küper, Christoph. 1995. "Metrics Today I: An Introduction." Poetics Today 16 (3): 389-409.

Ladd, D. Robert. 2008. Intonational Phonology. Second. Cambridge Studies in Linguistics 119. Cambridge: Cambridge University Press.

Landfester, Manfred, Hubert Cancik, and Helmuth Schneider. 2006. Brill's New Pauly: Encyclopaedia of the Ancient World. Leiden: Brill.

Laplace, Pierre Simon. 1812. Théorie Analytique Des Probabilités. Paris: Courcier.

Lardinois, André, and Diane J. Rayor. 2014. Sappho: A New Translation of the Complete Works. Cambridge: Cambridge University Press.

Legendre, Géraldine, Yoshiro Miyata, and Paul Smolensky. 1990. Harmonic Grammar: A Formal Multi-Level Connectionist Theory of Linguistic Well-Formedness: An Application. ICS Technical Report 90-4 CU-CS-464-90. Boulder, CO: University of Colorado, Boulder, Department of Computer Science.

Lehiste, Ilse. 1977. "Isochrony Reconsidered." Journal of Phonetics 5 (3): 253-263.

Lerdahl, Fred. 2001. "The Sounds of Poetry Viewed as Music." Annals of the New York Academy of Sciences 930 (1): 337-354.

Lerdahl, Fred, and Ray Jackendoff. 1983. A Generative Theory of Tonal Music. Cambridge, MA: MIT press.

Levitin, Daniel J., Jessica A. Grahn, and Justin London. 2018. "The Psychology of Music: Rhythm and Movement." Annual Review of Psychology 69 (1): 51-75.

Lewis, Fraser, Adam Butler, and Lucy Gilbert. 2011. "A Unified Approach to Model Selection Using the Likelihood Ratio Test." Methods in Ecology and Evolution 2 (2): 155-162.

Liberman, Mark. 1975. "The Intonational System of English." PhD diss., MIT.

Liberman, Mark, and Alan Prince. 1977. "On Stress and Linguistic Rhythm." Linguistic Inquiry 8 (2): 249-336.

Liddell, Henry George, Robert Scott, Henry Stuart Jones, and Roderick McKenzie. 1940. A Greek-English Lexicon. Oxford: Clarendon Press.

Lidov, Joel B. 2014. "Greek Metrics." Oxford Bibliographies.

London, Justin. 2002. "Cognitive Constraints on Metric Systems: Some Observations and Hypotheses." Music Perception 19 (4): 529-550.
—_. 2012. Hearing in Time. Second. Oxford: Oxford University Press.

Lotman, Mihail. 2008. "Metre: The Unknown." In Frontiers in Comparative Metrics: In Memoriam Mikhail Gasparov, edited by Maria-Kristiina Lotman and Mihail Lotman, 32-34. Tallinn: Tallinna Ülikooli Kirjastus.

Lynch, Tosca A.C. 2020. "Rhythmics." In A Companion to Ancient Greek and Roman Music, edited by Tosca A.C. Lynch and Eleonora Rocconi, 275-295. New York: Wiley. https://doi.org/10.1002/9781119275510.ch20.

Maas, Paul. 1962. Greek Metre. Translated by Hugh Lloyd-Jones. Oxford: Oxford University Press.

Magnuson, Karl, and Frank G. Ryder. 1970. "The Study of English Prosody: An Alternative Proposal." College English 31 (8): 789-820.

Malone, Joseph L. 1982. "Generative Phonology and Turkish Rhyme." Linguistic Inquiry 13 (3): 550-553.

Marchetti, Christopher C. 2009. "Aristoxenus Elements of Rhythm: Text, Translation, and Commentary with a Translation and Commentary on POxy 2687." PhD diss., Rutgers University.

Mastronarde, Donald J. 2013. Introduction to Attic Greek. Second. Berkeley: University of California Press.

Mathiesen, Thomas J. 1985. "Rhythm and Meter in Ancient Greek Music." Music Theory Spectrum 7:159-180.
—_ 1999. Apollo's Lyre: Greek Music and Music Theory in Antiquity and the Middle Ages. Vol. 2. Publications of the Center for the History of Music Theory and Literature. Lincoln, NE: University of Nebraska Press.

McCarthy, John J., and Alan Prince. 1986. "Prosodic Morphology." University of Massachussets and Brandeis University.
__ 1993. "Generalized Alignment." In Yearbook of Morphology, edited by Geert Booij and Jaap Van Marle, 79-153. Dordrecht: Springer.
—_ 1994. "The Emergence of the Unmarked: Optimality in Prosodic Morphology." North East Linguistics Society 24 (2): 333-378.
__ 1995. "Faithfulness and Reduplicative Identity." In Papers in Optimality Theory, edited by Jill N. Beckman, Laura Walsh Dickey, and Suzanne Urbanczyk, 249-384. University of Massachusetts Occasional Papers 18. Amherst, MA: Graduate Linguistic Student Association.

McElreath, Richard. 2020. Statistical Rethinking: A Bayesian Course with Examples in $R$ and Stan. Second. Boca Raton, FL: CRC Press.

McGill, R., W.A. Larsen, and J.W. Tukey. 1978. "Variations of Boxplots." The American Statistician 32:12-16.

Meillet, Antoine. 1923. Les Origines Indo-Européennes Des Mètres Grecs. Paris: Les Presses universitaires de France.

Michon, Pascal. 2016. "12. Rhythm from Art to Philosophy - Nietzsche (1867-1888) Part 5." Rhythmos 1 June 2016. Accessed January 28, 2021. http://rhuthmos.eu/ spip.php?article1892.

Middleton, Christopher. 1967. "Nietzsche on Music and Metre." Arion: A Journal of Humanities and the Classics 6 (1): 58-65.

Miles, Jeremy. 2014. "R Squared, Adjusted R Squared." In Wiley StatsRef: Statistics Reference Online. American Cancer Society. Accessed May 28, 2021. https:// onlinelibrary.wiley.com/doi/abs/10.1002/9781118445112.stat06627.

Mohri, Mehryar, Afshin Rostamizadeh, and Ameet Talwalkar. 2018. Foundations of Machine Learning. Second. Cambridge, MA: MIT Press.

Morton, John, Steve Marcus, and Clive Frankish. 1976. "Perceptual Centers (Pcenters)." Psychological Review 83:405-408.

Myrberg, Sara, and Tomas Riad. 2016. "On the Expression of Focus in the Metrical Grid and in the Prosodic Hierarchy." In The Oxford Handbook of Information Structure, edited by Caroline Féry and Shinichiro Ishihara, 441-462. Oxford: Oxford University Press.

Myung, In Jae. 2003. "Tutorial on Maximum Likelihood Estimation." Journal of Mathematical Psychology 47 (1): 90-100.

Nagy, Gregory. 1974. Comparative Studies in Greek and Indic Metre. Cambridge, MA: Harvard University Press.
__. 1992. "Metrical Convergences and Divergences in Early Greek." In Historical Philology: Greek, Latin, and Romance. Papers in Honor of Oswald Szemerényi, edited by Bela Broganyi and Reiner Lipp, 2:151-185. Amsterdam: John Benjamins Publishing Company.
2010. "Language and Meter." In A Companion to the Ancient Greek Language, 370-387. Blackwell Companions to the Ancient World. Oxford: Wiley-Blackwell.

Narmour, Eugene. 1990. The Analysis and Cognition of Basic Melodic Structures: The Implicationrealisation Model. Chicago: University of Chicago Press.

Nespor, Marina. 1990. "On the Rhythm Parameter in Phonology." In Logical Issues in Language Acquisition, edited by Iggy M. Roca. Linguistic Models 15. Dordrecht: Foris Publications.

Nespor, Marina, and Irene Vogel. 1986. Prosodic Phonology. Dodrecht: Foris Publications.
__ 1989. "On Clashes and Lapses." Phonology 6:69-116.

Nietzsche, Friedrich. 1986. Sämtliche Briefe. Edited by Giorgio Colli and Mazzino Montinari. Kritische Studienausgabe, Bd. 3. Berlin: De Gruyter.
1993. Werke: Kritische Gesamtausgabe, Abt. 2, Bd. 3: Vorlesungsaufzeichnungen (SS 1870-SS 1871). Edited by Giorgio Colli, Mazzino Montinari, Wolfgang Müller-Lauter, Karl Pestalozzi, Fritz Bornmann, and Mario Carpitella. Berlin: De Gruyter.

Nolan, Francis, and Hae-Sung Jeon. 2014. "Speech Rhythm: A Metaphor?" Philosophical Transactions of the Royal Society B: Biological Sciences 369 (1658).

Noyer, Rolf. 1997. "Attic Greek Accentuation and Intermediate Derivational Representations." In Derivations and Constraints in Phonology, edited by Iggy Roca, 501-528. Oxford: Oxford University Press.

O'Neill, Eugene G. 1939. "The Importance of Final Syllables in Greek Verse." Transactions and Proceedings of the American Philological Association 70:256-294.

Oldenberg, Hermann. 2005. Prolegomena on Metre and Textual History of the Rgveda. Metrische Und Textgeschichtliche Prolegomena, Berlin, 1888. Translated by M.A. Mehendale and V.G. Paranjape. Delhi: Motilal Banarsidass Publishers.

Olsen, Sarah. 2017. "Kinesthetic Choreia: Empathy, Memory, and Dance in Ancient Greece." Classical Philology 112 (2): 153-174.

Oras, Janika. 2019. "Individual Rhythmic Variation in Oral Poetry: The Runosong Performances of Seto Singers." Open Linguistics 5 (1): 570-582.

Pablos Martin, X., P. Deltenre, I. Hoonhorst, E. Markessis, B. Rossion, and C. Colin. 2007. "Perceptual Biases for Rhythm: The Mismatch Negativity Latency Indexes the Privileged Status of Binary vs Non-Binary Interval Ratios." Clinical Neurophysiology 118 (12): 2709-2715.

Page, Denys L. 1962. Poetae Melici Graeci. Oxford: Oxford University Press.

Palmer, Stephen E. 1977. "Hierarchical Structure in Perceptual Representation." Cognitive Psychology 9 (4): 441-474.

Paoli, Bruno. 2009. "Generative Linguistics and Arabic Metrics." In Towards a Typology of Poetic Forms: From Language to Metrics and Beyond, edited by Jean-Louis Aroui and Andy Arleo, 193-208. Language Faculty and Beyond 2. Amsterdam: John Benjamins Publishing Company.

Parker, L. P. E. 1976. "Catalexis." The Classical Quarterly 26 (1): 14-28.

Parry, Milman. 1930. "Studies in the Epic Technique of Oral Verse-Making: I. Homer and Homeric Style." Harvard Studies in Classical Philology 41:73-147.

Paschen, Elise, and Rebekah Presson Mosby. 2001. Poetry Speaks: Hear Great Poets Read Their Work from Tennyson to Plath. Naperville, IL: Sourcebooks.

Patel, Aniruddh D. 2008. Music, Language, and the Brain. Oxford: Oxford university press.

Patel, Aniruddh D., Anders Löfqvist, and Walter Naito. 1999. "The Acoustics and Kinematics of Regularly Timed Speech: A Database and Method for the Study of the p-Center Problem." In Proceedings of the 14 th International Congress of Phonetic Sciences, 1:405-408.

Pater, Joe. 2008. "Gradient Phonotactics in Harmonic Grammar and Optimality Theory." University of Massachussetts, Amherst.

- 2009. "Weighted Constraints in Generative Linguistics." Cognitive Science 33 (6): 999-1035.
__ 2016. "Universal Grammar with Weighted Constraints." In Harmonic Grammar and Harmonic Serialism, edited by John J. McCarthy and Joe Pater, 1-46. Bristol: Equinox Press.

Pearson, Lionel. 1974. "Catalexis and Anceps in Pindar: A Search for Rhythmical Logic." Greek, Roman, and Byzantine Studies 15 (2): 171-191.
—. 1990. Elementa Rhythmica. By Aristoxenus. Oxford: Clarendon Press.

Perusino, Franca. 1968. II Tetrametro Giambico Catalettico Nella Commedia Greca. Studi Di Metra Classica 5. Rome: Edizioni dell'Ateneo.

Phillips, Steven J., Robert P. Anderson, and Robert E. Schapire. 2006. "Maximum Entropy Modeling of Species Geographic Distributions." Ecological modelling 190 (3-4): 231-259.

Pöhlmann, Egert, and Martin L. West. 2001. Documents of Ancient Greek Music: The Extant Melodies and Fragments Edited and Transcribed with Commentary. Oxford: Oxford University Press.

Porson, Richard. 1802. Euripidis Hecuba. Cambridge: J. Burges.

Porter, James I. 2000. Nietzsche and the Philology of the Future. Stanford: Stanford University Press.

Pound, Ezra. 1960. ABC of Reading. Reading, Berkshire: Faber and Faber.

Powell, Jim. 2019. The Poetry of Sappho: An Expanded Edition, Featuring Newly Discovered Poems. Oxford: Oxford University Press.

Prince, Alan. 1983. "Relating to the Grid." Linguistic Inquiry 14:19-100.
__ 1989. "Metrical Forms." In Phonetics and Phonology, edited by Paul Kiparsky and Gilbert Youmans, vol. 1: Rhythm and Meter, 44-80. San Diego, CA: Academic Press.
—_ 1990. "Quantitative Consequences of Rhythmic Organization." Cls 26 (2): 355398.

Prince, Alan, and Paul Smolensky. 2004. Optimality Theory: Constraint Interaction in Generative Grammar. Malden, MA: Blackwell Publishing.

Probert, Philomen. 2006. Ancient Greek Accentuation: Synchronic Patterns, Frequency Effects, and Prehistory. Oxford: Oxford University Press.

Proto, Teresa. 2015. "Prosody, Melody and Rhythm in Vocal Music: The Problem of Textsetting in a Linguistic Perspective." Linguistics in the Netherlands 32 (1): 116-129.

Proto, Teresa, and François Dell. 2013. "The Structure of Metrical Patterns in Tunes and in Literary Verse. Evidence from Discrepancies between Musical and Linguistic Rhythm in Italian Songs." International Journal of Latin and Romance Linguistics 25 (1): 105-138.

Radford, Robert S. 1903. "The Latin Monosyllables in Their Relation to Accent and Quantity. A Study in the Verse of Terence." Transactions and Proceedings of the American Philological Association 34:60-103.

Rajendran, Vani G., Sundeep Teki, and Jan W. H. Schnupp. 2018. "Temporal Processing in Audition: Insights from Music." Neuroscience 389:4-18.

Raschka, Sebastian. 2018. "Model Evaluation, Model Selection, and Algorithm Selection in Machine Learning." arXiv:1811.12808, arXiv: 1811.12808.

Raven, David S. 1962. Greek Metre: An Introduction. London: Faber and Faber.
Riad, Tomas. 2009. "Accents Left and Right." In Versatility in Versification: Multidisciplinary Approaches to Metrics, edited by Tonya Kim Dewey and Frog, 123-146. Berkeley Insights in Linguistics and Semiotics 74. Berkeley: Peter Lang.
2017. "The Meter of Tashlhiyt Berber Songs." Natural Language and Linguistic Theory 35 (2): 499-548.

Rice, Curt. 1996. "Generative Metrics." Glot international 2 (7): 3-7.
—_ 2011. "Ternary Rhythm." In The Blackwell Companion to Phonology, edited by Marc van Oostendorp, Colin J. Ewen, Elizabeth Hume, and Keren D. Rice, vol. 5, 1228:1244. Malden, MA: Blackwell.

Rosch, Eleanor. 2002. "Principles of Categorization." In Foundations of Cognitive Psychology: Core Readings, edited by Daniel J. Levitin, 251-270. Cambridge, MA: MIT Press.

Rossbach, August, and Rudolf Westphal. 1867. Metrik Der Griechen Im Vereine Mit Den Ubrigen Musischen Kunsten. Bd 1: Griechisch Rhythmik Und Harmonik Nebst Der Geschichte Der Drei Musischen Disciplinen. Leipzig: Teubner.
——. 1868. Metrik Der Griechen Im Vereine Mit Den Ubrigen Musischen Kunsten. Bd 2: Griechische Metrik. Leipzig: Teubner.

Ruder, Sebastian. 2016. "An Overview of Gradient Descent Optimization Algorithms." arXiv:1609.04747, arXiv: 1609.04747.

Rudy, Stephen. 1976. "Jakobson's Inquiry into Verse and the Emergence of Structural Poetics." In Sound, Sign and Meaning: Quinquagenary of the Prague Linguistic Circle, edited by Ladislav Matejka, 477-520. Ann Arbor, MI: Michigan Slavic Contributions.

Ryan, Kevin M. 2011a. "Gradient Syllable Weight and Weight Universals in Quantitative Metrics." Phonology 28 (3): 413-454.
—_. 2011b. "Gradient Weight in Phonology." PhD diss., UCLA.
__. 2013. Against Final Indifference. Paper Delivered at M90 - Workshop on Stress and Meter. MIT.
2014. "Onsets Contribute to Syllable Weight: Statistical Evidence from Stress and Meter." Language 90 (2): 309-341.
——. 2016. Strictness Functions in Meter. Handout. MIT Phonology Circle.
__. 2017. "The Stress-Weight Interface in Metre." Phonology 34 (3): 581-613.
2019. Prosodic Weight: Categories and Continua. Vol. 3. Oxford Studies in Phonology and Phonetics. Oxford: Oxford University Press.
__. Forthcoming. "Syllable Weight and Natural Duration in Textsetting Popular Music in English."

Sale, William Merritt. 1993. "Homer and the Roland: The Shared Formular Technique, Part II." Oral Tradition 8:381-412.

Sauzet, Patrick. 1989. "L'accent Du Grec Ancien et Les Relations Entre Structure Métrique et Représentation Autosegmentale." Langages (24): 81-111.

Scheer, Tobias. 2011. A Guide to Morphosyntax-Phonology Interface Theories: How Extra-Phonological Information Is Treated in Phonology since Trubetzkoy's Grenzsignale. Berlin: Walter de Gruyter.

Schmidt, Johann Hermann Heinrich. 1868. Die Kunstformen Der Griechischen Poesie Und Ihre Bedeutung. Bd 1: Die Eurhythmie in Den Chorgesängen Der Griechen. Leipzig: Vogel.

Schön, Daniele, and Benjamin Morillon. 2018. "Music and Language." In The Oxford Handbook of Music and the Brain, edited by Michael H. Thaut and Donald A. Hodges. Oxford: Oxford University Press.

Schoubben, Nils. 2018. "How to Find the Origins of a Dragon? A Cognitive Linguistic. Approach towards the Proto-History of the Homeric Hexameter." PhD diss., Ghent University.

Schuh, Russell G. 1999. "Metrics of Arabic and Hausa Poetry." In New Dimensions in African Linguistics and Languages, edited by Paul Kotey F. A., 3:121-130. Trends in African Linguistics. Trenton and Asmara: Africa World Press, Inc.
___ 2001. "The Metrics of a Bole Song Style, Kona." UCLA.
——. 2010. "The Form and Metrics of Ngizim Songs." UCLA.
——. 2011. "Quantitative Metrics in Chadic and Other Afroasiatic Languages." Brill's Journal of Afroasiatic Languages and Linguistics 3 (1): 202-235.
__ 2014. "Where Did Quantitative Metrics in Hausa and Other Chadic Songs Come From." In 1st International Conference on Endangered Languages Kano, 4-6 August 2014, 1-15.

Schulkind, Matthew D. 1999. "Long-Term Memory for Temporal Structure:" Memory ध Cognition 27 (5): 896-906.

Selkirk, Elisabeth. 1984. Phonology and Syntax: The Relation between Sound and Structure. Cambridge, MA: MIT Press.
__ 1995. "The Prosodic Structure of Function Words." In Papers in Optimality Theory, edited by Laura Walsh Dickey and Suzanne Urbanczyk, 439-369. Amherst, MA: GLSA.

Shalizi, Cosma. 2015. Lecture 10: F-Tests, R2, and Other Distractions. 36-401, Section B, Fall 2015. Carnegie Mellon University. Accessed December 17, 2021. http: //www.stat.cmu.edu/~cshalizi/mreg/15/lectures/10/lecture-10.pdf.

Shattuck-Hufnagel, Stefanie, and Alice E. Turk. 1996. "A Prosody Tutorial for Investigators of Auditory Sentence Processing." Journal of Psycholinguistic Research 25 (2): 193-247.

Sicking, C. M. J. 1986. "Review of Greek Metre; Griechische Metrik, 4." Mnemosyne 39 (3/4): 423-432.
__ 1993. Griechische Verslehre. Vol. II.4. Handbuch Der Altertumswissenschaft. Munich: C. H. Beck.

Sievers, Eduard. 1893. Altgermanische Metrik. Halle: Max Niemeyer.
—__ 1912. Rhytmisch-Melodische Studien. Heidelberg: Winter.
Silva-Barris, Joan. 2011. Metre and Rhythm in Greek Verse. Wien: Austrian Academy of Sciences Press.

Simon, Júlia, and István Winkler. 2018. "The Role of Temporal Integration in Auditory Stream Segregation." Journal of Experimental Psychology: Human Perception and Performance 44 (11): 1683-1693.

Simons, Peter. 2019. "The Ontology of Rhythm." In The Philosophy of Rhythm: Aesthetics, Music, Poetics, edited by Peter Cheyne, Andy Hamilton, and Max Paddison, 62-75. Oxford: Oxford University Press.

Smolensky, Paul. 1986. "Information Processing in Dynamical Systems: Foundations of Harmony Theory." In Parallel Distributed Processing: Explorations in the Microstructure of Cognition, edited by David E. Rumelhart, James L. McClelland, and the PDP Research Group, vol. 1: Foundations, 194-281. Cambridge, MA: Bradford Books.

Smolensky, Paul, and Géraldine Legendre. 2006. The Harmonic Mind: From Neural Computation to Optimality-Theoretic Grammar. Cambridge, MA: MIT Press.

Snell, Bruno. 1962. Griechische Metrik. Third. Göttingen: Vandenhoeck and Ruprecht.

Steedman, Mark. 2014. "The Surface-Compositional Semantics of English Intonation." Language 90 (1): 2-57.

Steriade, Donca. 1988. "Greek Accent: A Case for Preserving Structure." Linguistic Inquiry 19 (2): 271-314.
—_. 2012. Intervals vs. Syllables as Units of Linguistic Rhythm. Handout.
. 2018. "Quantitative Rhythm and Saussure's Tribrach Law." In Proceedings of the 28th Annual UCLA Indo-European Conference, edited by David M. Goldstein, Stephanie W. Jamison, and Brent Vine, 231-266. Hempen: Bremen Verlag.

Stoyanova, Vessela. 2018. Against The Odds: An Exploration of Bulgarian Rhythms. Accessed March 6, 2021. https://www.fusionmagazine.org/against-the-odds-an-exploration-of-bulgarian-rhythms/.

Sugiura, Nariaki. 1978. "Further Analysis of the Data by Akaike's Information Criterion and the Finite Corrections." Communications in Statistics, Theory and Methods 7 (1): 13-26.

Suomi, Kari, Juhani Toivanen, and Riikka Ylitalo. 2008. Finnish Sound Structure. Vol. 9. Studia Humaniora Ouluensia. Oulu: Oulu University Press.

Suzuki, Seiichi. 2014. The Meters of Old Norse Eddic Poetry. Ergänzungsbände Zum Reallexikon Der Germanischen Altertumskunde 86. Berlin: De Gruyter.

Taliaferro, Robert Catesby. 1947. "On Music." In The Fathers of the Church, a New Translation, 4:237. Washington D.C.: Catholic University of America Press.

Tarlinskaja, Marina. 1976. English Verse: Theory and History. The Hague: Mouton.
__ 1989. "General and Particular Aspects of Meter: Literatures, Epochs, Poets." In Phonetics and Phonology, edited by Paul Kiparsky and Gilbert Youmans, vol. 1: Rhythm and Meter, 121-154. San Diego, CA: Academic Press.
2014. Shakespeare and the Versification of English Drama, 1561-1642. Surrey: Ashgate.

Tarlinskaja, Marina, and Lilya M. Teterina. 1974. "Verse-Prose-Meter." Linguistics 129:63-86.

Temperley, David. 1999. "Syncopation in Rock: A Perceptual Perspective." Popular Music 18 (1): 19-40.
——. 2001. The Cognition of Basic Musical Structures. Cambridge, MA: MIT Press.
——. 2019. "Second-Position Syncopation in European and American Vocal Music." Empirical Musicology Review 14 (1-2): 66-80.

Temperley, Nicholas, and David Temperley. 2013. "Stress-Meter Alignment in French Vocal Music." The Journal of the Acoustical Society of America 134 (1): 520-527.

Thomas, Richard F. 1990. "Past and Future in Classical Philology." Comparative Literature Studies 27 (1): 66-74.

Thompson, John. 1997. Music beyond Sound: Transcriptions of Music for the Chinese Silk-String Zither. Hong kong: John Thompson.

Toiviainen, Petri, and Joel S. Snyder. 2003. "Tapping to Bach: Resonance-Based Modeling of Pulse." Music Perception: An Interdisciplinary Journal 21 (1): 43-80.

Tomaševskij, Boris. 1923. Russkoe Stichosloženie: Metrika. Saint Petersburg.

Topintzi, Nina. 2008. "Weight Polarity in Ancient Greek and Other Languages." In Proceedings of the 8th International Conference on Greek Linguistics, August 30th - September 2nd, 2007, edited by George K. Giannakis, Mary Baltatzani, George J. Xydopoulos, and Anastasios Tsangalidis, 503-517. University of Ioannina.

Tortorelli, William. 2004. "A Proposed Colometry of Ibycus 286." Classical Philology 99 (4): 370-376.

Turk, Alice E., and Stefanie Shattuck-Hufnagel. 2007. "Multiple Targets of PhraseFinal Lengthening in American English Words." Journal of Phonetics 35 (4): 445472.
2013. "What Is Speech Rhythm? A Commentary on Arvaniti and Rodriquez, Krivokapić, and Goswami and Leong." Laboratory Phonology 4 (1).

Turner, Frederick, and Ernst Pöppel. 1983. "The Neural Lyre: Poetic Meter, the Brain, and Time On." Poetry 142 (5): 277-309.

Valiavitcharska, Vessela. 2013. Rhetoric and Rhythm in Byzantium. Cambridge: Cambridge University Press.
van der Hulst, Harry. 2014. Word Stress: Theoretical and Typological Issues. Cambridge: Cambridge University Press.
van der Weij, Bastiaan, Marcus T. Pearce, and Henkjan Honing. 2017. "A Probabilistic Model of Meter Perception: Simulating Enculturation." Frontiers in psychology 8:824.

Van Oostendorp, Marc. 2017. "The Head in Poetic Metrics." lingbuzz/003287.
van Ophuijsen, Johannes M. 1987. Hephaestion on Metre. Vol. 100. Mnemosyne, Biblioteca Classica Batava. Leiden: Brill.

Vaux, Bert. 1992. "Gemination and Syllabic Integrity in Sanskrit." The Journal of Indo-European Studies 20:283-303.

Vaux, Bert, and Neil Myler. 2011. "Metre Is Music: A Reply to Fabb and Halle." In Language and Music as Cognitive Systems, edited by Patrick Rebuschat, Martin Rohmeier, John A. Hawkins, and Ian Cross, 43-50. Oxford: Oxford University Press.

Vigorita, John F. 1976. "The Indo-European 12-Syllable Line." Zeitschrift für vergleichende Sprachforschung 90 (1/2): 37-46.
__. 1977. "The Indo-European Origin of the Greek Hexameter and Distich." Zeitschrift für Vergleichende Sprachforschung 91:288-299.
__. 1979. "The Trochaic Gāyatrı̄." Zeitschrift für vergleichende Sprachforschung 93 (2): 220-241.

Villing, Rudi C. 2010. "Hearing the Moment: Measures and Models of the Perceptual Centre." PhD diss., National University of Ireland Maynooth.

Vis, Jeroen. 2013. "Prosodic Word." Edited by George K. Giannakis. Encyclopedia of Ancient Greek Language and Linguistics, https://doi.org/http://dx.doi.org/10. 1163/2214-448X_eagll_COM_00000295.

Voigt, Eva-Maria. 1971. Sappho et Alcaeus. Fragmenta. Amsterdam: Polak \& van Gennep.

Vos, P.G. 1977. "Temporal Duration Factors in the Perception of Auditory Rhythmic Patterns." Scientific Aisthesis 1:183-199.

Wertheimer, Max. 1922. "Untersuchungen Zur Lehre von Der Gestalt." Psychologische forschung 1 (1): 47-58.

West, Martin L. 1970. "A New Approach to Greek Prosody." Glotta 48 (3/4): 185-194.
__ 1973a. "Greek Poetry 2000-700 B.C." The Classical Quarterly 23 (2): 179-192.
__. 1973b. "Indo-European Metre." Glotta 51 (3/4): 161-187.
—_ 1977a. "Sappho and Alcaeus." The Classical Review 27 (2): 161-163.
——. 1977b. "Tragica I." Bulletin of the Institute of Classical Studies 24 (1): 89-103.
—. 1982a. Greek Metre. Oxford: Oxford University Press.
__ 1982b. "Three Topics in Greek Metre." The Classical Quarterly 32 (2): 281297.
__ 1987. Introduction to Greek Metre. Oxford: Oxford University Press.
1992. Ancient Greek Music. Oxford: Clarendon Press.

West, Martin L. 1999. Greek Lyric Poetry: The Poems and Fragments of the Greek Iambic, Elegiac, and Melic Poets (Excluding Pindar and Bacchylides) Down to 450 BC. Oxford: Oxford University Press.
—. 2007. Indo-European Poetry and Myth. Oxford: Oxford University Press. 2015. "Iambic Poetry, Greek." Edited by Simon Hornblower, Antony Spawforth, and Esther Eidinow. The Oxford Classical Dictionary (Oxford), 720-721.

Wilamowitz-Moellendorff, Ulrich von. 1921. Griechische Verskunst. Berlin: Weidmannsche Buchhandlung.

Willink, Charles W. 2010. Collected Papers on Greek Tragedy. Edited by W. Benjamin Henry. Leiden: Brill.

Wilson, Colin, and Benjamin George. 2009. Maxent Grammar Tool. Accessed October 10, 2021. http://www.linguistics.ucla.edu/people/hayes/MaxentGrammarTo $\mathrm{ol} /$.

Winslow, Rosemary. 2012. "Meter." Edited by Steven Cushman, Clare Cavanagh, Jahan Ramazani, and Paul Rouzer. The Princeton Encyclopedia of Poetry and Poetics (Princeton), 872-876.

Wolf, Matthew. 2015. "Lexical Insertion Occurs in the Phonological Component." In Understanding Allomorphy: Perspectives from Optimality Theory, edited by E. Bonet, M-R. Llorat, and J. Mascaró, 361-407. Bristol: Equinox Press.

Wood, Simon. 2017. Generalized Additive Models: An Introduction with $R$. Second. Boca Raton, FL: CRC Press.

Youmans, Gilbert. 1983. "Generative Tests for Generative Meter." Language 59 (1): 67-92.
__ 1989. "Introduction: Rhythm and Meter." In Phonetics and Phonology, edited by Paul Kiparsky and Gilbert Youmans, vol. 1: Rhythm and Meter, 1-14. San Diego, CA: Academic Press.

Zec, Draga. 2007. "The Syllable." In The Cambridge Handbook of Phonology, edited by Paul De Lacy, 161-194. Cambridge: Cambridge University Press.

Zuraw, Kie, and Bruce Hayes. 2017. "Intersecting Constraint Families: An Argument for Harmonic Grammar." Language 93:497-548.


[^0]:    ${ }^{1}$ "Nothing is to be unexpected or sworn impossible" (Archilochus, fr. 122.1 Gerber; tr. Gerber 1999, p. 161). The transliteration of ancient Greek in this dissertation follows the scheme from Brill's New Pauly (Landfester et al. 2006).

[^1]:    ${ }^{2}$ This, of course, is a small fraction of the entire poetic output of the Greeks. For example, only $6.5 \%$ of Sappho (Lardinois and Rayor 2014, p. 7) and $7 \%$ of Sophocles' works (Finglass 2012, p. 10) is estimated to have survived, not to mention poets whose work has perished completely.

[^2]:    ${ }^{3}$ This is the consensus even today; see $\S 1.2 .1$ below.
    ${ }^{4}$ This view was antithetical to the mainstream 19 th century approach that had tried to interpret Greek versification based on the equal-timed rhythms and accents of Western art music (e.g., Boeckh 1811; Rossbach and Westphal 1867, 1868; Schmidt 1868).
    ${ }^{5}$ M. L. West is less skeptical. For example, according to West (1982a, p. 23), "our sense of a rhythm [...] corresponds to ancient understanding". Nevertheless, there is an unmistakable Nietzschean ring in West's claim that Greek verse patterns are more intricate than our "banal and repetitive rhythms" (ibid., p. 25), and that they are "representable only by changing time-signatures and bar-lengths" (1992, p. 135). As Pearson (1990, p. xlii) points out, these are assumptions that cannot be proved on the surviving evidence; see also Sicking (1986, p. 429).

[^3]:    ${ }^{6}$ Not entirely: traditional Finnish and Estonian folk song meters regulate both syllable weight and word stress simultaneously (Ryan 2017).

[^4]:    ${ }^{7}$ Unless, of course, Greek poetry is not actually metrical at all, as some imagist poets of early 20th century claimed about Greek lyric (e.g., Pound 1960, p. 204). But the facts suggest otherwise (e.g., the undeniable regularities in syllabic patterning, near-definite line lengths, reuse of the same patterns across poems and by different authors, etc.).

[^5]:    ${ }^{8}$ MaxEnt and ME are alternative abbreviations that appear in the literature.

[^6]:    ${ }^{9}$ Of course, syllables (Zec 2007) and syllable weight (Gordon 2017) are abstractions, too. But MPs add another layer of abstraction, being slots for syllables.
    ${ }^{10}$ Confusingly, also syllables that can scan either as $L$ or $H$ depending on context are called anceps (West 1982a, p. 8). But they have nothing to do with anceps MPs, which are slots for syllables.

[^7]:    ${ }^{11}$ The formulations in the parentheses are mine. Asterisks $\left({ }^{*}\right)$ indicate unmetrical sequences.

[^8]:    ${ }^{12}$ There is an invariable word-break (i.e., a CAESURA) between the two - (West 1982a, p. 44). A natural explanation for why $*--$ is here constantly violated is that the caesura was meant to be accompanied by some extra interval of time, filled either by lengthening the first - or by silence.
    ${ }^{13}$ Abritta (2015) argues that there is a weak agreement between pitch accents and culminative positions in Homeric poetry.

[^9]:    ${ }^{14}$ Ryan (2019, p.138) extends the typology to meters that are often characterized as "syllable-counting", such as French (Biggs 1996) and Tocharian B (Bross et al. 2015). I have excluded them here, since they are not quantitative in the sense of being based on syllable weight.
    ${ }^{15}$ Recent work in metrics suggests that the counting of moras in these (and other similar meters) should not be taken literally. The seemingly arbitrary count of moras (5 or 7) is here due to a short pause at the end of each line, revealing that each line in fact has eight moraic "beats". More examples and the relevant references are given in §2.2.2.1.

[^10]:    ${ }^{16}$ Besides being well documented in Indo-European poetries (both ancient and modern), truncation is attested in Arabic (Paoli 2009), Hausa (Schuh 2011), Japanese (Cole and Miyashita 2006), Somali (Banti and Giannattasio 1996), Tashlhiyt Berber (Dell and Elmedlaoui 2008), to name just a few. Across traditions, the most common form of truncation appears to be catalexis.

[^11]:    ${ }^{1}$ Visual poetry such as picture poems and acrostics are a historically rare exception.

[^12]:    ${ }^{2}$ Scholars of ancient Greek meter have long known that interpreting the textual patterns sometimes only makes sense in a musical context (e.g., Dale 1968, p. 14).

[^13]:    ${ }^{3}$ Metrical verses are often characterized as complete rhythmic figures (e.g., Kiparsky 1977; Hayes 1989b; Prince 1989). It is then probably not a coincidence that across verse traditions, lines tend to be 2-4 seconds long in recitation (Turner and Pöppel 1983).

[^14]:    ${ }^{4}$ The cyclic nature of meter was already understood by Augustine of Hippo ( 4 th -5 th c. CE). He writes that "[without music] you could in no way mark how far the combination of feet runs forward and from where it returns to begin again" (De musica 3.1, trans. Taliaferro 1947). The idea can be traced even further back to a Greek fragment (Schol. B. in Heph. 3, Consbruch 1906, pp. 257-261), which speaks about epiploké or "interweaving", meaning (as summarized by Dale 1968, p. 41) that "in the same infinite series $\times-\smile-\times-\smile-\times-\smile[\ldots]$, it is possible to mark off both iambic and trochaic segments, in $\smile \smile-\cup \smile-\cup \smile-\smile \smile[\ldots]$ dactylic and anapaestic, and so on."

[^15]:    ${ }^{5}$ In fact, labeled trees and bracketed grids differ in an important regard: unlike grids, trees make it possible to specify different weights for weak positions. I will return to this issue in §4.1.3.1.

[^16]:    ${ }^{6}$ As Hayes and Schuh (2019, p. e265) note, HHLH is mostly used line-initially and can be analyzed as an initial licensing phenomenon, on which see $\S 1.3 .3$ of this dissertation.

[^17]:    ${ }^{7}$ Golston and Riad (2000).
    ${ }^{8}$ Golston (1998).
    ${ }^{9}$ Blumenfeld (2015).

[^18]:    ${ }^{10}$ Ternary stress systems exist too (e.g., Cayuvava, Estonian), but there is a huge phonological literature analyzing these systems without sacrificing binarity; see Rice (2011) for discussion and references.

[^19]:    ${ }^{11}$ Note that both the branching and non-branching MPs must here correspond to two gridmarks at the sub-tactus level. Otherwise the S positions would clash rhythmically with the SW of the subdivided W positions; and the (at least implicit) branching of all MPs is in any case required by Prince's (1989, p. 55) Maximal Articulation principle, according to which all metrical structure is binary.

[^20]:    ${ }^{1}$ This is a nearly verbatim quote from Pater's (2008, p. 2) characterization of the main challenge of phonotactics, which I have here adapted for metrics.
    ${ }^{2}$ A rare example of a quantitative meter that has a strict requirement for uniformity is the Persian motaqāreb meter (Hayes 1979), which only allows patterns of the form $\checkmark--\cup--\smile--\smile-$.

[^21]:    ${ }^{3}$ Kiparsky (1975, p. 611), by contrast, had considered linearly ordered metrical rules.
    ${ }^{4}$ Other disciplines where converging constraints have played a central role before OT are music theory (Lerdahl and Jackendoff 1983) and Gestalt psychology (Wertheimer 1922; Asch 1946).

[^22]:    ${ }^{5}$ For alternatives exploring input-output pairs in metrical analysis, see Hayes (2009), M. E. Adams (2011), Hammond (2012), and Blumenfeld (2015).

[^23]:    ${ }^{6}$ Constraint violations assign penalties, so it makes sense to mark them using negative integers (Pater 2009).

[^24]:    ${ }^{7}$ This is shorthand notation for $\sum_{x \epsilon X} \hat{p}(x) f(x)$, due to Dudík et al. (2004).

[^25]:    ${ }^{10}$ It may also be pointed out that models are not hypotheses (e.g., McElreath 2020, pp. 4-5): there are many models that could correspond to the same hypothesis, and vice versa. Moreover, a hypothesis (such as "poetic meter is always binary") could suggest multiple causative models (i.e., "the language faculty cannot count above 2 " or "the cognition of rhythm is biased towards binary structures"), which again statistical models are not; statistical models are about associations between variables. A systematic comparison of different causative models or hypotheses about Greek meter is outside the scope of this dissertation.

[^26]:    ${ }^{11}$ The corpus includes all of Athenaeus, Diodorus Siculus, Herodotus, Polybius and Thucydides, all downloaded from the Perseus Digital Library (Crane (ed.) 2020). The total number of word tokens in the corpus is 268482 .

[^27]:    ${ }^{12}$ I also tried using trigrams, which produces more fluent text, but also makes verse generation unacceptably slow.

[^28]:    ${ }^{13}$ A caveat: when using informative priors (as is the case here), $\mathrm{AIC}_{c}$ cannot be applied blindly (McElreath 2020, p. 219). Specifically, it can be shown that when the regularization factor employed by the model approaches $\infty$, the effective number of parameters (i.e., degrees of freedom) of the model $\rightarrow 0$ (e.g., Wood 2017, p. 83). Recall that the $\mathrm{AIC}_{c}$ value uses $K$, the number of estimated parameters (see the formula in (6) above). In the present case, the low $\sigma^{2}$ of the baseline-prior almost fixes the parameter in question, so the effective degrees of freedom can be approximated as $K-1$.
    ${ }^{14}$ The constraints formulated here are intended for an analysis of the mora-based meters that the majority of Greek poetry is written in. The syllable-based quantitative meters used by, e.g., Sappho and Alcaeus, would require slightly different constraints (see Chapter 5 for discussion).
    ${ }^{15}$ In the actual timing of prosodic patterns, it is not the syllable onsets that are regulated in order to achieve perceptual isochrony, but a point within the syllable closer to the following vowel (i.e., the "p-center"; e.g., Morton et al. 1976; Patel et al. 1999; Villing 2010). In a recent article, Ryan (forthcoming) shows that it is the p-center that best characterizes weight in the textsetting of English pop songs, instead of syllable rimes (e.g., Halle and Vergnaud 1987, and later work) or vowel-to-vowel intervals, which have been recently revived as a contender for the standard syllable theory of syllable weight (Steriade 2012). The extent to which meter responds to the phonetic detail of language is an interestingly open area of research, as Ryan points out.

[^29]:    ${ }^{16}$ In musical meter, a syllable can be stretched out across multiple notes (in what is called a melisma), and so have multiple attack points of pitch-events. For simplicity, I assume that poetic meters only care about the left edges of syllables; for discussion on this point see Dell and Elmedlaoui (2008, pp. 28-29).
    ${ }^{17}$ Hence I call them "constraints" (as in Optimality Theory) instead of "features", which would be the corresponding term in machine learning (see $\S 3.3$ above).

[^30]:    ${ }^{18}$ The constraint is intentionally formulated as $S T R O N G \Rightarrow$ LONG, instead of $S T R O N G \Rightarrow H$. The latter would imply that "squeezed" H syllables would not incur a violation, which is clearly not the case. In syllable-based quantitative meters, such as those of Vedic and Aeolic Greek, however, Strong $\Rightarrow \mathrm{H}$ is a plausible constraint.

[^31]:    ${ }^{19}$ Hayes et al. (2012) call these constraints by different names: *No Fall from S and *No Rise from W. I have removed the double negative (*No), and use Rise to strong in place of *No Rise from W, which means exactly the same thing.

[^32]:    ${ }^{1}$ By the same token, dactylic hexameters and elegiac distichs (thousands of lines of which survive) would have been good candidates. I leave it for future work to examine them, however, due to their elusive synchronic structure (Barnes 1986), oral-formulaic character (e.g., Parry 1930; Sale 1993) and possible Indo-European origins (e.g., Haug and Welo 2001; Kiparsky 2018), which complicate matters considerably. With the exception of the comic variant of the iambic trimeter, I have also excluded verses from Greek comedies, which tend to follow metrical rules of their own (e.g., Perusino 1968; West 1982a, p. 88; 92; 94).

[^33]:    ${ }^{2}$ The affinity of iambic and trochaic meters is also evident in that both were associated in Archaic verse (c. 650-550 BCE) with similar topics such as satire, sex, and joking (íambos = "lampoon", LSJ, s.v.) as well as with more serious poetry (West 2015, p. 720).

[^34]:    ${ }^{3}$ In particular, the génos iambikón ("iambic genus") was consistently associated with a 1:2 ratio (lógos) of rhythmic units (e.g., Plato, Republic 3.400c; Aristotle, Rhetoric 1409a; Aristoxenus, Elements of rhythm 30-31, etc. The ancients also identified a rhythm with a $3: 2$ ratio, called paián ("paean"; e.g., Aristoxenus, ibid. 30), but it appears to have never been associated with the iambic rhythmic genre (for the ancient references and discussion, see Silva-Barris 2011, p. 79-92).

[^35]:    ${ }^{4}$ This shows that bracketed grids and labeled trees are in fact not formally equivalent (cf. Kiparsky 2020, p. 2), grids being more restrictive. There is, however, an important exception to the rule that grids can only be combined with gridmark-indexed constraints: final strictness and initial laxness effects (see §1.3.3). They progress gradiently towards the ends of lines (Fabb 2002, pp. 173-175) and possibly other constituents (Arrazola 2021), affecting entire constituents instead of grid columns of equal height. This is arguably not reason enough to choose labeled trees over bracketet grids, precisely because the incidence of strictness effects progresses gradiently across metrical constituents (Ryan 2019, p. 139), instead of being neatly indexable to some specific grouping structure.

[^36]:    ${ }^{5}$ A possible musical parallel is the singing of the first notes of a melody with an undetermined pitch, as in some Tedaga (a Saharan language) singers do; see deCastro-Arrazola (2018, p. 89).

[^37]:    ${ }^{6}$ In the line-final metron, resolution is seen only about $0.5 \%$ of the time. In superstrong positions the rate is on average slightly higher at $0.8 \%$.

[^38]:    ${ }^{7}$ In fact, the real lines nearly always have a prosodic word boundary at the caesura. Thus, the condition that there must be an orthographic space after the first colon produces somewhat unrealistic pseudolines. For example, the second nonsense line of (8) has the function word $e k$ "from" (LSJ, s.v.) ending at the caesura - not a prosodic word boundary, since in Greek prosodic words are generally lexical words plus any preceding function words (Vis 2013). Improving the verse generation algorithm to produce more authentic caesuras is a task for future work.

[^39]:    ${ }^{8}$ How much the constraint budges from the prior depends on the value of $\sigma_{i}^{2}$. The value I use, 0.001 , is arbitrary; I leave for future work to investigate possible alternatives to this choice.

[^40]:    ${ }^{9}$ Interestingly, a similar aesthetic effect has been associated with English trochees, such as Blake's The Tyger (S. Adams 1997, p. 55). Furthermore, one study found that in Swedish trochaic verse the initial syllables of trochaic feet are just 1.25 times longer than foot-final syllables; in Swedish iambs the ratio was about 2 (Fant et al. 1991); similarly in German poetry (e.g., Kruckenberg and Fant 1993, Bröggelwirth 2006). These differences can be analyzed as stemming from the so-called IAMBIC/TROCHAIC LAW (Hayes 1985, 1995; Hay and Diehl 2007), according to which iambs and trochees are durationally asymmetrical, durational contrasts being naturally grouped as iambs and intensity contrasts as trochees.

[^41]:    ${ }^{10}$ A small number of trochaic tetrameters, too, have a postponed main caesura, but most of them are in comedies.

[^42]:    ${ }^{11}$ In fact, $\mathrm{LONG} \Rightarrow$ STRONG is not completely absolute: a handful of tragic iambic trimeters start with the sequence HL (e.g., Aeschylus, Seven Against Thebes 488: Hippomédontos...: HLLHH..., ), which can be understood as line-initial syncopation. There are no such lines in my dataset, however, and so to simplify the analysis I treat $\operatorname{LONG} \Rightarrow$ STRONG as an inviolable pattern constraint. Syncopation in Greek meter is the subject of Chapter 5.

[^43]:    ${ }^{12}$ Note that the negatively weighted *SQueEze rewards squeezing in any anceps, including the last one where H is less frequent than L. As a correction, *SqueEze(Clausula) must be assigned with a somewhat higher weight than would be the case if *SQueEze only penalized $H$ in the first two ancipitia.

[^44]:    ${ }^{13}$ For the other two ancipitia, there was no statistically significant difference between L and H in lines with a late vs. early caesura.

[^45]:    ${ }^{14}$ Another way to test for the $\stackrel{S}{\mathrm{H}}$ mapping in the comic trimeters would be a comparison of the rhymes of the H syllables here and in other positions. It is widely thought (e.g., Ryan 2011a, and the references therein) that VC rhymes are phonologically lighter than VV in H syllables. I leave this scrutiny to a later occasion.

[^46]:    ${ }^{15}$ As West (1977b) discusses, the (ancient) practice of arranging tragic recitative anapests as dimeters is not entirely satisfactory, since there are many periods with an odd number of metra, and based on the phrasing patterns the periods could alternatively be set out as trimeters and tetrameters. Nevertheless, dimeter phrases are most frequent and seem to be the "basic" type in anapests (see also Dale 1968 , p. 49).

[^47]:    ${ }^{16}$ Melic anapests are not included, as they would require a separate analysis due to their distinct rhythmic character (e.g., Dale 1968). In addition, I have excluded dimeters ending in LL, which are occasionally found in the texts. Since such lines violate brevis in longo (see §1.3.2), it can be assumed that they are not real dimeters but parts of some longer period.

[^48]:    ${ }^{17}$ And indeed, a model that includes just $\operatorname{Strong} \Rightarrow$ Long, Superstrong $\Rightarrow$ Long, and Hyperstrong $\Rightarrow$ LONG gets a $R_{\text {adj }}^{2}$ value as low as 0.302 .

[^49]:    ${ }^{18}$ Namely, there are 569 instances of HLLHH but only 316 of LLHHH and 267 of HHHH in my dataset.
    ${ }^{19}$ The other candidates violating Superstrong $\Rightarrow$ Long (e.g., HHHLL, LLLLHH) are either ruled out by ${ }^{*}$ LLL or made improbable by the strongly-weighted Hyperstrong $\Rightarrow$ Long.
    ${ }^{20}$ This analysis also shows that line charts and other visualizations (e.g., the tables and figures above) can easily be misleading-as Ryan (2014, p. 323) puts it, "in showing only unigram propensities, [they] overlook certain syntagmatic tendencies".

[^50]:    ${ }^{21}$ See Golston and Riad (2000, p. 157-158) for arguments that the truncation could be at either end of the line; and see $\S 6.2 .1 .1$ below for discussion.

[^51]:    ${ }^{1}$ Greek lyric is an umbrella term that is used in a "comprehensive" and "narrow" sense. Lyric in the comprehensive sense covers "more or less all the Greek poetry of the centuries down to 350 BC " (West 1999, p. vii), excluding only hexameters and drama. The narrow definition in addition excludes iambs and elegies, making lyric equal to the heterogeneous category of "melic" or sung poetry (mélos $=$ "song", LSJ, s.v.). On the various meanings of Greek lyric in the history of classical scholarship, see Budelmann (2009).

[^52]:    ${ }^{2}$ See, however, Schoubben (2018) for a critical review of Kiparsky's theory.
    ${ }^{3}$ Ancient theory, however, only uses the term anaclasis to denote the difference between the ionic dimeter $(\checkmark \cup--\cup \cup--)$ and the so-called anacreontic $(\checkmark \cup-\cup-\cup--)$, which it analyzes as an anaclastic variant of the former. The more general ancient term denoting syllabic inversion appears to have been metáthesis (see Gentili and Lomiento 2003, pp. 28-29 and p. 40).

    In descriptive Greek metrics, "syncopation" has a different meaning: it refers to the responsion between $-\smile$ or $\smile-$ with a "trisemic" $-($ West 1982a, p. 22).
    ${ }^{4}$ The valuable discussion of "inverse feet" in ancient metrical theory by Silva-Barris misses one important ancient citation: a fragment of Hephaestion (Consbruch 1906, p. 77), which is our only source explicitly discussing metáthesis in Greek meter.

[^53]:    ${ }^{5}$ In his textbook of Greek metrics, however, West characterizes anaclasis as "something like syncopation in the proper musical sense" (1982a, p. 24).

[^54]:    ${ }^{6}$ Kiparsky (2018, p. 86) distinguishes between three kinds of syncopation in an iambic metron (WSWS). He calls early syncopation in the first foot CHORIAMBIC, late syncopation anywhere in the pattern IONIC and early syncopation in the second foot GLYCONIC. The less specific notions of early and late syncopation will suffice for the present purpose.

[^55]:    ${ }^{7}$ It might be objected that syncopation in Chadic may be Arabic in origin, which in turn is influenced by the Persian (IE) tradition (Kiparsky 2018, p. 102). But according to Schuh (2014, p. 7), syncopated patterns in Chadic languages cannot all have come from an earlier Arabic tradition, since Islamic influence in some areas where syncopation is attested is very recent (second half of 20 th century).
    ${ }^{8}$ For consistency with the previous examples, this section sticks to using the L and H symbols. The following section (§5.3) reverts to the traditional notation ( $\smile,-$, and $\times$ ). The numbering of Sappho and Alcaeus' fragments is from Voigt (1971).

[^56]:    ${ }^{9}$ Kiparsky (2018, p. 98) uses trees instead of grids; the two are here equivalent.

[^57]:    ${ }^{10}$ It may also be relevant that although the Aeolic base can occur line-internally in so-called composite patterns (on which see $\S 5.3 .5$ below), its realization as LL is only attested after a word boundary (Silva-Barris 2011, p. 108); conceivably, a short rest may have occurred before it (ibid., p. 109). In tragedy, the glyconic colon with LL in the Aeolic base $(\checkmark \cup-\cup \cup-\cup-)$ does appear sporadically; but since it only responds with itself, Itsumi (1984) argues that it is not a glyconic at all. In the present framework, however, it could be interpreted as having a "resolved" Aeolic base but with the first $L$ truncated $(\wedge \backsim)$. This would be a possible explanation for why the pattern does not respond with normal acatalectic glyconics.

[^58]:    ${ }^{11}$ A fragment of Hephaestion (Consbruch 1906, p. 77) states explicitly that ditrochees and ionics are "cognate by metathesis" (syngenés [...] katà metáthesin).

[^59]:    ${ }^{12}$ There seems to be no alternative identity for a trochaically-analyzed 2 io in the glyconic family (as with $2 i o{ }^{\prime}={ }_{\wedge} " h i$; see above). One could, however, analyze it as ${ }_{\wedge} a d+a d$, or a fusion of the first half of ${ }_{\wedge} " h i$ and the second half of $h i{ }^{*}$. But there appears to be no point in engaging in such colometric trickery.

[^60]:    ${ }^{13}$ Berg (1978) argues, by contrast, that internal expansion is a late Greek innovation, on the basis that it is not attested in Vedic; Kiparsky (2018) follows Berg's view. West (2007, p. 49), however, offers examples of Vedic verse forms that can be interpreted as internally expanded.
    ${ }^{14}$ "Now among all the women of Lydia she stands out, just as, once the sun's finished setting, the rosy-fingered moon surpasses all the stars, spreading her light alike on the salt sea and over all the wide blossoming country meadows" (tr. Powell 2019, p. 24).

[^61]:    ${ }^{15}$ Kiparsky's theory, however, only allows late syncopation to occur metron-internally (the only exception being 2io*). Assuming that $g l^{d}$ is a trimeter with catalexis, the analysis proposed here has a late syncopation crossing the second and third metra (positions 8 and 9). As far as I can see, there are no serious consequences if the requirement for metron-internal syncopation is relaxed, however; far more important is that syncopation is avoided across caesuras (Kiparsky 2018, pp. 114-116).

[^62]:    ${ }^{16}$ The list excludes asynartetic patterns, i.e., those that ancient theory analyzes as having mixed rhythms disconnected by an (almost) invariable caesura in between (see, e.g., Voigt 1971, p. 20; van Ophuijsen 1987, pp. 137-160; Gentili and Lomiento 2009).

[^63]:    ${ }^{17}$ Voigt (1971, p. 16) mistakenly scans the 11 th position of the second line and the 5 th position of the third one as $\smile$; according to Voigt's own edition (ibid., p. 136) they should both be - , and I treat them as such here. See also West (1977a, p. 162), who points out the errors.

[^64]:    ${ }^{1}$ Blumenfeld (2015) proposes a different purely phonological approach to metrical analysis. It differs from PM in that it does not abolish templates-Blumenfeld argues that 1) their structures are not always predictable, 2) native speakers have intuitions about them, and that 3) differences in templates and actual verses must be distinct (ibid., pp. 84-85). Blumenfeldian templates, however, fall within the purview of linguistics by being abstract prosodic representations instead of rhythmic ones (cf. Riad 2017). Although it would make some sense to consider Blumenfeld's theory alongside the PM approach, here I focus on the latter, hoping to return to Blumenfeld's proposal in future research.

[^65]:    ${ }^{2}$ Unmarked properties (e.g., ${ }^{*}$ CODA) are not part of the description because they are not distinctive for this morpheme. Interestingly, linear order is also not necessary: it follows from the universal sonority hierarchy and syllable geometry (onset, nucleus, coda) (e.g., Clements 1990). To account for pairs like cat [kæt] and tack [tæk] that differ only in their linear order of segments, Direct OT uses Align-L from Prince and McCarthy's alignment theory (1993): distinctive violations must be close to the beginning of the word. Golston's theory has not sparked much discussion (Krämer 2012, p. 210); but see Klein $(2000,2003)$ for a theory based on similar ideas.

    As Wolf (2015, p. 3) points out, the lexical encoding of markedness violations allows for contrastive syllabification: a * CODA desideratum can distinguish between forms such as at.a and a.ta. There is a broad consent that syllabification is never contrastive (e.g., Krämer 2012, p. 88); the theory thus overgenerates. Another concern about Golston's theory is that desiderata are basically constraints with negative weight, something that most researchers do not think should be allowed to happen in phonological analysis (e.g., Pater 2009).

[^66]:    ${ }^{3}$ Mora clashes could theoretically happen if isolated L syllables could be parsed into their own feet. But according to Kager (1993) such degenerate feet (Hayes 1995, pp. 86-105) are never parsed if that would incur a mora clash.

[^67]:    ${ }^{4}$ The final syllable of es.tin is parsed L, because word-final consonants are extrametrical in Greek (see, e.g., Blumenfeld 2004).
    ${ }^{5}$ In their own words, GR "parse the meter into the feet that Greek used and see what patterns emerge" (p. 111). In practice, GR simply use '(x.)' as a substitute for $H$ and $L L$ and '? for $L$ in each MP.

[^68]:    ${ }^{6}$ It is not clear to me why GR include ${ }^{*}$ CLASH in their analysis. The most frequent metron, HHLH, violates * Clash, but LHLH does not. The other patterns that violate *CLASH occur 246 times in total in my dataset, and those that do not, 181 times. In other words, if *CLASH does play some role in Greek iambs, the poets clearly prefer violating it.

[^69]:    ${ }^{7}$ In later work, the authors analyze Greek lyric meters using similar principles as GR (Golston and Riad 2005). For reasons of space, I will not discuss those analyses here.

