THE HOMERIC HEXAMETER AND A BASIC PRINCIPLE OF METRICAL THEORY

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THIS article addresses itself to two fundamental issues in Greek metrics, one theoretical and the other methodological. The first is the most basic question that can be raised in the description of any metrical system: what and how many are the constituent, structural elements of that system, and what is their relation to the language employed for the system? The second concerns the logic of statistical arguments adduced in the solution of the first. Specifically we give a detailed examination of Irigoin's claims for the Homeric hexameter, the clearest and most cogent presentation of the currently favored metrical doctrine that there is a multiplicity of metrical elements in Greek corresponding to postulated differences in the phonetic duration of phonemes and syllables. We begin by noting this doctrine's divergence from the theory of the ancient μετρικοί, then set forth briefly the logic underlying hypotheses such as Irigoin's, and point out the improbability of the system posited, which would be quite unparalleled among the metrical systems of the world. Following a complete presentation of the data on which Irigoin's claims rest, in a detailed exposition of the logical and mathematical principles involved, we assess the statistical arguments for a multiplicity of metrical units, and demonstrate that they are unfounded and circular, and that the data at issue are merely the automatic reflex of Greek linguistic structure when it is fitted to independent (nondurationally motivated) aspects of metrical structure. This result is achieved by the following steps: we first argue that Wernicke's Law is an important factor in accounting for the data, but that it cannot be the only factor. We then isolate and quantify the remaining, externally motivated, metrical and linguistic factors and are thereby able to confirm the null hypothesis (that durational factors are not involved) and thus the invalidity of Irigoin's claims and assumptions. We conclude that there is no basis for such recent attempts to refute the traditional analysis, dating to antiquity, that in Greek there are only two metrically relevant distinctive elements, *longum* and *breve*, which stand respectively in a one-to-one correspondence to linguistically heavy and light syllables. We emphasize that statistical evidence obtained from metrical sources cannot be used directly to establish any given hypothesis about metrical structure. Such evidence must be interpreted against the values that would result from the interaction of the distributional properties of the language and the independent requirements of the meter.

1. INTRODUCTION

The oldest tradition in the study of Greek meter, dating to the ancient μετρικοί, recognizes two and only two distinctive metrical elements in a one-to-one ("biunique"[1]) relation to linguistic syllables. Among modern metrists, by contrast, there has been a growing propensity to seek a multiplicity of metrical elements corresponding to (certain categories of) syllabo-segmental durations. The latter approach, which traces its ancestry ultimately to the *συμπλέκοντες*[2] (Aristid. Quint. 38. 15 W-I) rather than to the *μετρικοί*, we find, for example, at the beginning of the last century with Seidler—"Harum igitur litterarum pronuntiationem habuisse aliquid coniicias, unde communis regulae violatio commode veniam inveniret"[3]—and more recently, for example, in Sommer,[4] Zielinski,[5] Snell,[6] Porter,[7] West,[8] and Irigoin.[9] Although the authors are generally less than explicit about the practical consequences of such statements for the structure of the meter, they are basically claiming that the traditional category of heavy or long syllables contains a number of subcategories ("shorter longs" and "longer shorts"), and that, because the poet chooses between them in an apparently nonrandom manner, these subcategories are metrically relevant. This is obviously a hypothesis of the most fundamental import for the nature and structure of Greek meter, though one which is immediately suspect because, as we shall see (§ 3), it is at variance with a universal principle of metrical systems (whether quantitative, stress-based, or tone-based). For the most part the justification for the proliferation of metrical elements has been sought in various zeugma (bridge) phenomena and presumed restrictions on the form of resolutions.[10] This approach has generally been applied in an ad hoc manner alongside the standard assumption of *longum* and *breve*, and perhaps only West and Irigoin have recognized its full import. West's durational interpretation of a variety of phenomena, including even dialect

1. For the term see N. Chomsky, "The Logical Basis of Linguistic Theory," *Proc. IX Int. Congr. Ling.* (The Hague, 1962), pp. 951 ff.; for its applicability to metrical theory see Devine and Stephens, "The Abstractness of Metrical Patterns: Generative Metrics and Explicit Traditional Metrics," *Poetics* 16 (1975): 411–30.

2. The essential difference between the *μετρικοί* and the *ῥυθμικοί* is succinctly summed up at Funaioli, *Gramm. Rom. Frag.*, 304. 132: "Rhythmici temporibus syllabas, metrici tempora syllabis finiunt." For the ancients, those who maintained the distinction between the two approaches were called *χωρίζοντες*; those who conflated the two, *συμπλέκοντες*. Cf. Arist. Quint. 38. 15 W-I: *Οἱ μὲν οὖν συμπλέκοντες τῇ μετρικῇ θεωρίᾳ τὴν περὶ ῥυθμῶν τοιαύτην τινὰ πεποίηνται τὴν τεχνολογίαν. οἱ δὲ χωρίζοντες ἑτέρως ποιοῦσιν.* None of the modern scholars mentioned in this article is a rhythmist either in the ancient sense or in the sense that L. Pearson, "Catalexis and Anceps in Pindar," *GRBS* 15 (1974): 171–91, could be called rhythmical; they rather continue the tradition of the *συμπλέκοντες*.

3. A. Seidler, *De versibus dochmiacis*, pars posterior (Leipzig, 1812), p. 385.

4. F. Sommer, "Zur griechischen Poesie, I: Die Positionsbildung bei Homer," *Glotta* 2 (1909): 145–240.

5. T. Zielinski, *Tragodoumenon libri tres*, vol. 2 (Cracow, 1925), pp. 150 et passim.

6. B. Snell, *Griechische Metrik*[3] (Göttingen, 1962), pp. 11–13.

7. H. Porter, "The Early Greek Hexameter," *YClS* 12 (1951): 1 ff., esp. 20.

8. M. West, "A New Approach to Greek Prosody," *Glotta* 48 (1970): 185–94.

9. J. Irigoin, review of L. Rossi (see n. 11), *GGA* 217 (1965): 228 ff.

10. Particularly with regard to *muta cum liquida* and other intervocalic segments, where it is wholly unwarranted and arises from simple fallacies in logic and statistics: see Stephens, "The Myth of the *Lex de positione debili* and a Fundamental Question in Metrical Theory," *Phoenix* 29 (1975): 171–80.

variations, is at variance with well-established principles of linguistics and metrics. Since Irigoin, on the other hand, presents a clear and sophisticated argument based on entirely new evidence, our discussion here will be specifically directed to his treatment.

2. EVIDENCE OF DIONYSIUS

Irigoin, in his review of a monograph by L. Rossi,[11] attempts to justify the assertions of the rhythmists reported by Dionysius of Halicarnassus concerning the ἄλογος μακρά of the dactylic hexameter and the nature of the cyclic anapest. It is to be regretted that what he has to say did not appear in a format more commensurate with its fundamental importance. According to the rhythmists, as Dionysius is usually thought to be telling us, the *longum* of the cyclic anapest is not durationally equal to that of the normal anapest, and similarly the *longum* of the dactyl is distinct from (shorter than) true long (= *biceps?*):

> *Οἱ μέντοι ῥυθμικοὶ τούτου τοῦ ποδὸς τὴν μακρὰν βραχυτέραν εἶναί φασι τῆς τελείας, οὐκ ἔχοντες δ' εἰπεῖν ὅσῳ, καλοῦσιν αὐτὴν ἄλογον. ἕτερός ἐστιν ἀντίστροφον ἔχων τούτῳ ῥυθμόν, ὃς ἀπὸ τῶν βραχειῶν ἀρξάμενος ἐπὶ τὴν ἄλογον τελευτᾷ· τοῦτον χωρίσαντες ἀπὸ τῶν ἀναπαίστων κυκλικὸν καλοῦσι.* [*Comp.* 70. 17 U-R]

Irigoin's stated purpose is merely to support, with unusually detailed linguistic and statistical arguments, the rhythmists' claim for the μακρά βραχυτέρα, but in order to do so he makes much stronger claims of his own, the validity of which is quite independent of anything found in Dionysius. Irigoin offers evidence in the form of statistics, produced by his pupil Miss Seguin, showing different frequencies of syllable types (e.g., C$\breve{V}$C, C$\bar{V}$, etc., and subcategories thereof) in the *longum* and contracted *biceps*, from which he concludes: "la structure phonétique du longum est différente de celle du biceps."[12]

This assertion was, perhaps, less critically received than it might have been, because many scholars labor under the *biceps* fallacy and therefore are predisposed to see in such data a welcome confirmation of the distinction between *biceps* and *longum* as they interpret it. This fallacy is a variant of the *anceps* fallacy, which we have exposed in a recent paper.[13] In brief, the fallacy assumes that metrical transformation rules cannot produce merger of underlying distinctive elements; specifically in the case of *biceps* it assumes, "if ever different, then always different." An adequate theory of Greek meter, on the other hand, must operate with underlying representations of the metrical structure (e.g., – ⏑ ⏑) and surface representations of the same (e.g., – –) which are derived from them by transformational rules (e.g., contraction rule: ⏑ ⏑ ⟶ –). The linguistic syllables are mapped onto the surface representations (e.g., heavy syllable ⟶ long metrical

11. L. Rossi, *Metrica e critica stilistica* (Rome, 1963).
12. Review of Rossi, p. 230.
13. Devine and Stephens, "Anceps," *GRBS* 16 (1975): 197–215.

element at the surface level). This framework reveals in exactly what respects *longum* and contracted *biceps* are identical and in what respects they are not, and it shows how a transformational rule can perfectly well produce a merger. Therefore, whether *longum* and contracted *biceps* are distinct at the surface level, too, cannot be decided by preconceived constraints on what a metrical transformation rule can do. If they are to be distinct at the surface level, they must have different linguistic implementations. Irigoin thinks he has found the necessary linguistic evidence. Where a single surface element (-) has been posited, Irigoin now assumes two or more unspecified, durationally based, distinctive elements, the implementation of which is achieved through distinctive frequency distributions of the different durational classes of heavy syllables.[14] The merits of the statistical argument we discuss in the rest of the paper: meanwhile the reader should note that the claim reported by Dionysius (as Irigoin understands it) would automatically follow from the validity of Irigoin's statistical argument, but the reverse is *not* the case, since rhythmical contrasts do not necessarily imply correlated metrical contrasts,[15] as the ancients themselves recognized (cf. Aristoxenus at Psellus 8 [Pighi]: *τῶν δὲ χρόνων οἱ μὲν εἰσι ποδικοί, οἱ δὲ τῆς ῥυθμοποιίας ἴδιοι*).

3. LOGICAL ALTERNATIVES

In evaluating the differences between the frequency distributions of the various types of syllables (henceforward these differences discovered by Irigoin and Seguin will be referred to as I-S differences), it is vital to remember that theoretically there are two possibilities. Either they are due to *deliberate* implementation of a characteristic of the metrical structure, as Irigoin claims, or they are merely the *automatic* result of fitting one given structure (the Greek language, or, more precisely, the Homeric *Kunstsprache*) with another given structure (the dactylic hexameter as it is traditionally conceived). In the latter case the I-S differences necessitate no new theoretical construct, and the traditional binary distinction between *longum* and *breve* should be maintained. It is precisely the latter crucial alternative that Irigoin has failed to consider, and which we shall here show to be the case.

14. A system that might be viewed as parallel in the functioning of frequency distributions, but which in fact remains quite different from that suggested by Irigoin, because there are only two metrically relevant units, is found in the Finnish Kalevala, where the underlying trochaic pattern is realized by distinctive frequency distributions of the two, prominent and nonprominent, metrical units. It should be clearly understood, however, that in the Kalevala meter there are only two metrically distinctive types of syllable (though their specification is rather complex) and not four or more, as Irigoin would have for Greek. For a statistical approach to metrical analysis see, e.g., Jiří Levý, "Mathematical Aspects of the Theory of Verse," in L. Doležel and R. Bailey, eds., *Statistics and Style* (New York, 1969), pp. 95–112; and Jerzy Woronczak, "Statistische Methoden in der Verslehre," *Poetics*, vol. 1 (The Hague, 1961), pp. 607–624. A transformational approach is always a theoretical possibility, and the current controversy between traditional and generative metrics comes down largely to a choice between the two alternatives: see further Devine and Stephens, "The Abstractness of Metrical Patterns."

15. Dionysius' report refers to rhythmical units, Irigoin's to metrical ones. The difference is as obvious as it is basic: for further discussion see our forthcoming monograph, *New Approaches to Greek Metrics*.

4. THE DATA

Within the category of heavy syllable, Irigoin distinguishes about twenty syllable types, which are intended to reflect supposed durational gradations. These are, for the purposes of statistical sampling, at any rate, then grouped into three classes ($C\breve{V}C$, $C\bar{V}$, and $C\bar{V}C$);[16] we are not told whether these classes correspond precisely to what is relevant to the meter or this reduction is only for convenience: "dans la pratique certains de ces types se confondent."[17] The durational hierarchy thus established for the three categories is not impossible from a general phonetic point of view, although its literal interpretation may involve gross oversimplification, since acoustic measurements in a number of languages suggest that diverse factors over and above the mere segmental structure of the syllable condition syllabic duration. However, it would be most unusual for such differences to function as the distinctive properties of metrical elements. Indeed, examination of a large number of the metrical systems of the world indicates a universal rule that metrical elements are always implemented by a single feature with only two values: a binary categorization (in Greek, syllable weight which is either heavy or light).[18] That Greek meter should be an exception to this universal rule is another of the very strong claims that Irigoin does not appear to realize that he is making.

The statistics that Irigoin presents are drawn from the first four feet of the hexameter (from a sample of one hundred lines of *Odyssey* 14), and show a significantly higher frequency (more than chance) of the shorter types of syllables (broadly $C\breve{V}C$) in the *longum* than in the contracted *biceps*, and conversely a significantly higher frequency of the longest types ($C\bar{V}C$) in the contracted *biceps* than in the *longum* (no figures are given for $C\bar{V}$, but it is reported as behaving comparably to $C\bar{V}C$). Irigoin gives data explicitly

16. C denotes any consonant, $\breve{V}$ any short vowel, and $\bar{V}$ any long vowel or diphthong. (The representations refer, of course, to post-sandhi forms: see n. 24.) It has long been recognized for Greek, and our examination of the quantitative metrical systems of a number of languages tends to confirm, that the presence or absence of any number of syllable initial consonants is irrelevant to syllable quantity. Also irrelevant is the presence or absence of more than a single final, closing consonant in a syllable with a short vowel. Since this is the case and since Irigoin accepts these principles for his third category of syllables (long vowels or diphthongs followed by a final consonant), we may make a concession to readability and tolerate a slight ambiguity in our notation. A syllable initial C is understood to indicate zero or any number of consonants, whereas a syllable final C indicates at least one final consonant, since the absence of any consonant is clearly marked by omitting the C (as in $C\bar{V}$ as opposed to $C\bar{V}C$).

For the purposes of the metrical data discussed here, we must distinguish between, on the one hand, what we may call full-word boundary and all greater boundaries, and, on the other, what we may call appositive boundary and all lower ranking boundaries. We use the symbol # for full-word and greater boundaries (an example would be Ἀργείων#κράτεει) and the hyphen - for lower ranking boundaries, including no boundary (examples would be εἶς-δέ-τις or ἀσ-πίδα). In our notation the final syllable of Ἀργείων# will be represented as -$C\bar{V}C$#, and the syllable ἀσ- of ἀσ-πίδα as -$C\breve{V}C$-. For an attempt to provide a principled account of boundary problems in Greek on the basis of metrical evidence, see our "Greek Appositiva: Towards a Linguistically Adequate Definition of Bridge and Caesura" (forthcoming).

17. Review of Rossi, p. 229.

18. For a discussion of metrical feature systems, see Devine and Stephens, "The Abstractness of Metrical Patterns," pp. 411 ff.

only for C$\breve{V}$C (which for him excludes syllables ending in a resonant ρ, λ, μ, ν) and for C$\bar{V}$C. His data are given in Table 1.[19]

TABLE 1

	C$\breve{V}$C	C$\bar{V}$C
longum of the dactyl	24.0%	3.5%
longum of the spondee	19.5%	7.5%
contracted *biceps*	8.0%	15.0%

We have checked Irigoin's sample and can confirm that in fact the contracted *biceps* does prove to differ from each of the two *longa* more than chance alone would explain. In a statistical sense, the difference is significant: it remains to determine whether it has any metrical significance.

We shall depart from Irigoin's procedure in that we operate with only three basic categories (C$\breve{V}$C, C$\bar{V}$, C$\bar{V}$C) and in that we class C$\breve{V}$ + resonant with C$\breve{V}$C rather than with C$\breve{V}$. The substance of the I-S difference is not materially affected by these changes in procedure. We should note, however, that, owing to changes in the classification of C$\breve{V}$ + resonant, the difference between the *longum* of the spondee and the contracted *biceps* becomes greater than that between the *longum* of the dactyl and the contracted *biceps*. In our work we added samples from a number of books of the *Iliad* and the *Odyssey* and from various later authors to provide a diachronic check. A remarkable consistency was found from Homer to the twentieth century: Table 2 gives the I-S differences for the *longum* of the dactyl (Dact. L.), the *longum* of the spondee (Sp. L.), and the contracted *biceps* (Sp. B.). This very consistency, however, is a cause for doubting that durational considerations have anything to do with the observed I-S differences, for it seems unlikely that McKenzie especially, whose translation of the *Aeneid* passage into Homeric hexameters appeared in 1910,[20] should have so faithfully reflected the as yet undiscovered Homeric I-S differences. Of course, McKenzie may have unconsciously internalized the differences from his reading of Homer, but the suspicion remains that his respect of the I-S differences is merely the automatic reflex of other factors that were well known at the time.

We next examined the first four feet of the hexameter independently in order to check the stability of the I-S differences throughout the line. Table 3 presents the data for the *longum* of the spondee (L) versus the contracted *biceps* (B) for all spondees in the first four feet of *Odyssey* 2, along with the chi-square.[21] Clearly the difference is greatest in the fourth foot, and nearly

19. Review of Rossi, pp. 229–30.

20. R. McKenzie, *Vergil, Aeneid II. 268–385 Translated into Homeric Hexameters*, Gaisford Prize for Greek Verse (Oxford, 1910).

21. The chi-square test is a statistical procedure for determining whether two (or more) samples (here of *longum* and *biceps*) are significantly different, i.e., different to an extent greater than would arise through chance variation in samples of the same population. The value χ^2 is a measure of the deviations of the relevant frequencies in the samples. In this case it is calculated by adding the ratios obtained when the squares of each of the differences between the observed and expected number of occurrences (*not* the percentages) of the respective syllable types are divided by the

nonexistent in the first. An interesting fact emerges from the data collected for Table 3. When the *biceps* of the first foot is compared to the *biceps* of the fourth, if we accept for the moment Irigoin's premise that I-S differences reflect durational differences, we find that the first contracted *biceps* is significantly shorter than the fourth (the differences in the syllable frequen-

TABLE 2

		CV̆C	CV̄	CV̄C	Number counted
Homer *Iliad* 3, 12; *Odyssey* 1, 14	Dact. L.	43.74%	48.43%	7.83%	1086
	Sp. L.	46.30%	41.25%	12.45%	514
	Sp. B.	27.24%	62.06%	10.72%	
Hymn to Aphrodite	Dact. L.	38.40%	49.05%	12.55%	263
	Sp. L.	44.53%	46.71%	8.76%	137
	Sp. B.	26.28%	64.96%	8.76%	
Aratus	Dact. L.	40.07%	52.84%	7.09%	282
	Sp. L.	44.07%	51.96%	4.24%	118
	Sp. B.	27.97%	68.46%	3.39%	
Nonnus 2	Dact. L.	37.99%	49.02%	12.99%	502
	Sp. L.	50.00%	32.65%	17.35%	98
	Sp. B.	23.47%	65.31%	11.22%	
McKenzie	Dact. L.	39.07%	47.35%	13.58%	302
	Sp. L.	50.00%	32.65%	17.35%	98
	Sp. B.	27.55%	63.27%	9.18%	

TABLE 3

		CV̆C	CV̄	CV̄C	Number of spondees counted	χ^2
Foot 1	L	39.60%	52.35%	8.05%	149	0.08
	B	38.93%	53.69%	7.38%		
Foot 2	L	40.74%	47.62%	11.64%	189	4.91
	B	29.63%	58.73%	11.64%		
Foot 3	L	32.85%	51.09%	16.06%	137[a]	3.61
	B	32.85%	58.39%	8.76%		
Foot 4	L	46.10%	39.72%	14.18%	141	21.13
	B	23.40%	66.67%	9.93%		

[a] The number of spondees in the third foot in Book 2 (64) is too small for a reliable estimate; it has therefore been supplemented with a sample from *Od.* 14.

corresponding expected number of occurrences: it is the sum of the ratios (observed — expected)²/(expected) for each syllable type. The expected values are calculated on the hypothesis that the samples are the same, and are based on the combined sample. For tables such as those in the text (which have two degrees of freedom) a value of $\chi^2 = 5.99$ is considered to indicate a significant difference. For a detailed explanation of chi-square, see G. Herdan, *The Advanced Theory of Language as Choice and Chance*, Kommunikation und Kybernetik, 4 (New York, 1966), pp. 36 ff. and 404 ff.

cies give $\chi^2 = 8.13$). We shall not speculate whether Irigoin's procedure would require increasing yet again the number of durationally distinct metrical elements to account for the above interpodic differences.

5. Independent metrical factors in I-S differences

We have pointed out above that, to establish the desired significance for the I-S differences, it is necessary to demonstrate that they are not merely the reflex of independent, long-known metrical and/or linguistic factors. We proceed a fortiori to examine the fourth foot, where the I-S differences are the most pronounced. Even an elementary familiarity with the hexameter would suggest that these differences must somehow be related to Wernicke's Law, that in spondee-ending words positionally lengthened C$\breve{V}$C (-C$\breve{V}$C#C-) is avoided in the *biceps* of the fourth foot (and probably in the *biceps* of other feet also—"Extended Wernicke's Law"). This metrical phenomenon, by definition, contributes to the overall I-S difference, especially in the fourth foot; yet, unfortunately, Wernicke's Law is a factor omitted from any consideration in Irigoin's brief treatment.

6. Wernicke's law

Two questions have to be answered. (1) Is Wernicke's Law motivated by the same factors that are assumed to motivate the I-S differences in general, i.e., is it durationally motivated, or independent of duration? (2) Is Wernicke's Law by itself responsible for the I-S differences in the fourth foot or is it only a contributing factor? The former question we shall discuss in this section, the latter in § 7.

A durational basis for Wernicke's Law has been posited in the past most notably by Sommer.[22] Stifler[23] sought to rebut Sommer's theory by pointing out *inter alia* that Wernicke's Law is part of a more general tendency to avoid all word boundaries at contracted position 8 (the spondee zeugma), and that the final syllable types eliminated by Wernicke's Law (-C$\breve{V}$C#C-, -C$\breve{V}$#CC-) are just those that become light syllables in different sandhi conditions.[24] Obviously there are more locations in the verse available for words that vary in their quantitative shape (e.g., those ending in C$\breve{V}$C) than for words whose shape is constant (e.g., those ending in C$\bar{V}$C). Furthermore, almost by definition, a word can be more easily avoided in a given metrical position accordingly as there are other positions in which it can occur. Therefore, it is easier to satisfy the restrictions on word boundary at contracted position 8 for variable word shapes than for fixed word shapes. Viewed in this light, it is clear that Wernicke's Law is a reflex of the spondee zeugma and consequently will have the same motivation, so that it requires no additional assumptions about the metrical acceptability of different

22. "Zur griechischen Poesie, I," esp. p. 193.
23. T. Stifler, "Das Wernickesche Gesetz und die bukolische Dihärese," *Philologus* 79 (1924): 323.
24. Sandhi (from Sanskrit *sam* + *dha*, "put together") is a term covering the different phonological modifications that words undergo when they come into contact. Such modifications in Greek are traditionally classified as, e.g., elision, aphaeresis, crasis, epic correption, and, of course, the well-known rules of syllabification in the metrical line of which we are speaking here.

syllabic durations. In fact Wernicke's Law is really only the limiting case of a much more general hierarchy of avoided syllable types. This line of argument is fully exploited by W. Sidney Allen,[25] who sets up a hierarchy of syllable types: -V̆C, -*αι/οι*, -*η/ω*, -*ῃ/ῳ*, -V̄C. The more frequently a syllable is measured light antevocalically (a value which increases from right to left in the preceding hierarchy), the rarer its appearance in contracted position 8 (the frequency of occurrence increases from left to right). That is, V̆C before a vowel is light with only very rare exceptions, and it is almost totally absent anteconsonantally in contracted position 8; similarly, -*αι/οι* are the most frequently correpted long nuclei and are correspondingly rare in 8; and so on. The central section—vowels and diphthongs—of Allen's hierarchy is the familiar epic correption hierarchy.[26] The precise, inverse relation between the two hierarchies is completely accounted for by the fact that the more frequently a final syllable is correpted or shortened, the greater its potential for occurrence elsewhere in the line becomes. We suspect[27] that a similar avoidance hierarchy will appear as a consequence of the parallel avoidance of word boundary in contracted positions 4 and 6 (Extended Wernicke's Law). Of course, final heavy syllables of polysyllabic words are less frequent in position 4 than in 8 (4.72% as opposed to 17.30%, calculated from E. O'Neill's data[28]), so that the overall frequency of CV̆C, -*αι/οι*, etc., will be affected to a correspondingly smaller degree in position 4: this correlates well with the smaller values of the I-S differences observed in position 4 (see Table 3).

However, the durationalists would probably consider this hierarchy to be rather one of phonetic duration, word boundary being avoided the more insistently, the shorter the duration of the final syllable in question. Now potential occurrence elsewhere would have to be invoked in any case if, as claimed by Stifler, word boundary at position 8 tends to occur more frequently when the offending word could not be transposed to the end of the hexameter because that position is already occupied by another word of the same or comparable shape, or by a fixed formula. Consequently, the introduction of a durational element into the explanation constitutes a loss of economy, unless it can be argued that duration, too, has an autonomous place in the explanation of Wernicke's Law because it provides the motive for the overall avoidance of word boundary at contracted position 8. Thus the durationalists would presumably argue that all final long syllables are shorter than medial and initial long syllables, or that word boundaries reduce the duration of a preceding syllable. But this is an unprovable hypothesis for Greek and invalid as a linguistic universal. In any case most durationalists claim that the complex of boundary phenomena has exactly

25. W. Sidney Allen, *Accent and Rhythm* (Cambridge, 1973), p. 290.

26. P. Chantraine, *Grammaire homérique*, vol. 1³ (Paris, 1958), p. 89. Note that the avoidance hierarchy in position 8 should affect the frequency of CV̄ as well.

27. We did not actually complete the gathering of the relevant statistics: previous authors offer only subjective reactions.

28. E. O'Neill, "The Localization of Metrical Word Types in the Greek Hexameter," *YCIS* 8 (1942): 103–178. Word shapes relevant to positions 7 and 8 must be separated and their frequencies in those two positions converted to percentages.

the opposite effect.[29] Thus, Porter[30] explains the spondee zeugma under discussion here as a result of the fact that long finals are "more effectively long than other syllables"; and, in West's[31] durational scheme, word end adds length to both short and long syllables. Irigoin himself had adopted a similar position for the trimeter bridges,[32] without apparently realizing that, if finals are longer, the claim that the contracted *biceps* is preferentially implemented by longer longs, so far from explaining why word boundary is avoided at contracted position 8, would in fact require the reverse (i.e., high frequency of final syllables) for its validity. The durationalists thus are caught in a contradiction. Until the durational effect of boundaries can be assessed on grounds that are neither circular nor ad hoc, any account involving durational assumptions must remain scientifically inadequate.

If duration is removed as a general motive for the avoidance of word boundary at contracted position 8, it becomes, as noted above, superfluous as a motive for Wernicke's Law. But in that case, a satisfactory general motive has to be found to replace duration. A simple theory is avoidance of false coda, i.e., avoidance of line final patterns internally within the line. This theory has the virtue of providing a unified explanation for both the spondee zeugma and Hermann's Bridge, but it is less apt for comparable phenomena in earlier feet and only partially accounts for the fifth foot. The (statistically unassessed) permissibility of a major syntactic break after contracted position 8[33] is perhaps not a great problem for the false-coda theory, since it is remarkable how often the distinction between simple word boundary and higher ranked syntactic boundaries is disregarded for metrical purposes. As far as position 8 goes, the permissibility of major syntactic breaks is adequately accounted for by Allen's stress theory.[34] (Allen assumes that there is a metrically relevant linguistic stress which is assigned from word end to alternate heavy syllables or matrices of two light syllables according to phonological context.) Both Allen's theory and the false-coda theory present some difficulties, but at least neither suffers the mutual contradiction implicit in the durational explanation of the laws of Wernicke and Porson. (If only one of these laws is to be durationally motivated, it is more likely to be Porson's than Wernicke's. Even then the segmental structure of syllables would remain irrelevant for Porson's Law.)

7. THE CONTRIBUTION OF WERNICKE'S LAW TO THE OVERALL I-S DIFFERENCE

In this section we shall give a quantitative analysis of the contribution of Wernicke's Law to the overall I-S difference between position 7 and con-

29. The two boundary classes relevant here are discussed in n. 16 above.

30. Porter, "The Early Greek Hexameter," p. 20. For durational allophones of pre- and post-boundary positions, see I. Lehiste, "Juncture," *Proceedings of the Fifth International Congress of Phonetic Sciences* (Basel, 1965), pp. 172–200, and E. Gårding, *Internal Juncture in Swedish*, Travaux de l'Institut de phonétique de Lund, 6 (Lund, 1967).

31. West, "A New Approach to Greek Prosody."

32. Irigoin, "Lois et règles dans le trimétre iambique et la tetramétre trochaïque," *REG* 72 (1959): 74.

33. H. Ehrlich, *Untersuchungen über die Natur der griechischen Betonung* (Berlin, 1912), p. 160.

34. *Accent and Rhythm*, pp. 286–95.

tracted position 8. The essential reasoning behind this analysis is as follows: if Wernicke's Law and the spondee zeugma constitute the only causes of the I-S difference, then the distribution of syllable types in position 8 must be nothing more than a modification of the distribution in position 7 produced by Wernicke's Law and the spondee zeugma. In other words, those factors contributing to the frequency of C$\breve{V}$C which are not subject to Wernicke's Law and the spondee zeugma should be the same in position 8 as in position 7, and those factors that are subject to Wernicke's Law and the spondee zeugma in position 8 should be so modified that their contribution to the frequency of C$\breve{V}$C in position 8 is decreased enough to account for the I-S difference. This hypothesis constitutes the null hypothesis, in contrast to the assumption that other factors are involved. In order to check the null hypothesis, we shall isolate those factors which are subject to Wernicke's Law and the spondee zeugma and devise a means of calculating the decrease in the frequency of C$\breve{V}$C produced in position 8 by Wernicke's Law and the spondee zeugma. Then we shall compare the actually observed I-S difference with the difference that is projected on the null hypothesis. If the projected difference is not significantly different from the observed I-S difference, then Wernicke's Law and the spondee zeugma will be shown to be the only causes of the I-S difference. Specifically we shall show that, for a large sample, the actual difference in C$\breve{V}$C frequency between position 7 and position 8 is 20.91%, whereas Wernicke's Law and the spondee zeugma by themselves would yield a difference of 6.44%. Therefore, although Wernicke's Law and the spondee zeugma make an important contribution to the I-S difference, they cannot be the only factors involved.

Monosyllables. Before we begin to calculate the effect of Wernicke's Law and the spondee zeugma on the frequency of C$\breve{V}$C, we must take note of an important statistical property of the Greek language which combines with Wernicke's Law to reduce the frequency of C$\breve{V}$C in position 8. This property concerns monosyllables, and consequently a separate examination of the syllable-type frequencies in the various types of monosyllables is a necessary prerequisite for calculating the contribution of Wernicke's Law and the spondee zeugma to the I-S difference.

The great majority of monosyllables are, of course, either prepositives followed by reduced "juncture" (καί-, οὐ-, ἐν-, etc.) or postpositives followed by full "juncture" (-γάρ, -μέν, -τις, etc.), only a few being full phonological words (βῆ).[35] Postpositives and phonological words will be very nearly eliminated from position 8 by the spondee zeugma, and those few that remain will be subject to Wernicke's Law, so that C$\breve{V}$C types will be eliminated. This means that only prepositives are left as a source of C$\breve{V}$C syllables among the monosyllables of position 8. The statistical property of the Greek language referred

35. Junctures are phonologically relevant categorizations of morphological and syntactic boundaries. The term is currently out of favor in linguistics but worth preserving: see our article, "Boundaries in Phonology, a Preliminary Analysis," in A. Juilland, ed., *Linguistic Studies Presented to Joseph Greenberg* (Saratoga, Calif., 1976). We may speak here of full juncture, occurring at word and greater boundaries, and reduced juncture, occurring at appositive and lesser boundaries. For the sake of brevity we shall call syllables followed by full juncture "junctural syllables" (S# in our notation: cf. n. 16). In accordance with Wernicke's Law and certain properties of the Greek language discussed in the text, for the purposes of frequency calculations we shall also distinguish nonjunctural syllables of polysyllabic words (S-) from monosyllables (mono, S) and prepositives (pre).

to in the preceding paragraph is that in prepositives the frequency of C$\breve{V}$C is much lower than the average frequency of C$\breve{V}$C in all types of monosyllables. In fact, as an extensive sample of prose (excluding the article) shows, only 20% of prepositive monosyllables have C$\breve{V}$C structure. Thus, in qualitative terms, the spondee zeugma serves to decrease the frequency of C$\breve{V}$C in position 8 by selecting from the class of all monosyllables an overwhelming majority that have a very low frequency of C$\breve{V}$C. Wernicke's Law makes its contribution by removing all C$\breve{V}$C's from such nonprepositives as may occur.

We must now analyze the situation quantitatively. As we have seen, for monosyllables there are three relevant properties: (a) that of being prepositives; (b) that of not being prepositives; and (c) that of having C$\breve{V}$C structure. Prepositives, nonprepositives, and C$\breve{V}$C monosyllables will each have their own frequency in position 8. Each of these frequencies can be viewed as a simple probability: e.g., the chance of finding a prepositive in position 8 is simply the fraction of all syllables in (a large sample of) position 8 that are prepositive. Thus, if we take a large sample of position 8, say, n syllables (and therefore n hexameter verses), and find m prepositives in that sample, the probability of a prepositive in position 8 is m/n. Likewise, if we find k C$\breve{V}$C syllables (whether monosyllables or parts of polysyllabic words), then the probability of C$\breve{V}$C in position 8 is k/n. (These are, of course, simply the relative frequencies.) Now both prepositives and nonprepositives may have C$\breve{V}$C structure, so that each type will have its own frequency of C$\breve{V}$C in the language. Frequencies of this latter kind can be viewed as conditional probabilities. For example, if we choose a large sample of prepositives only (from a prose text), say, r prepositives, and out of those r prepositives we find that s have C$\breve{V}$C structure, then s/r is the conditional probability that, if a syllable of the language is a prepositive, then it will have C$\breve{V}$C structure. Notice that to get a sample of prepositives we have to select them from a text consisting of all kinds of syllables. The total number of syllables that we go through before we get r prepositives, say, q, will, of course, be very much larger than r: $q > r$. There is yet another kind of probability that we shall find useful, namely joint probability, or the chance that a syllable will have two specified properties. To continue with the present example, we have q syllables of all kinds, r of these are prepositives, and of those r, s have C$\breve{V}$C structure. The joint probability that a syllable selected from this sample will be prepositive and have C$\breve{V}$C structure is s/q. Notice that the joint probability is equal to the product of the simple probability and the corresponding conditional probability: $s/q = r/q \times s/r$. Prose descriptions of calculations involving the three kinds of probability rapidly become awkward; so let us introduce some abbreviatory notation. Since the probabilities we are dealing with are the frequencies of the various kinds of syllables, we shall use f to denote probability (or frequency). When we are dealing with probabilities in a metrical context, a subscript 7 or 8 will be used to distinguish the probabilities in positions 7 and 8 respectively. Thus f_8(C$\breve{V}$C) denotes the simple probability of any kind of C$\breve{V}$C syllable in position 8. To denote a conditional probability we shall use a subscript abbreviation of the conditioning property. Thus f_{pre}(C$\breve{V}$C) is the conditional probability that, if a syllable is a prepositive, it has C$\breve{V}$C structure. As mentioned in the preceding paragraph, this conditional probability is 20%, so we can write f_{pre}(C$\breve{V}$C) = 20%. It should be noted that both metrical position and the conditioning property of a conditional probability are denoted by subscripts: this reflects the fact that all the probabilities calculated for a metrical position are logically conditional probabilities. Joint probability is denoted by writing the abbreviations for the two relevant properties on the line in parentheses: e.g., f_8(mono, C$\breve{V}$C) denotes the probability of finding in position 8 a monosyllable that has C$\breve{V}$C structure.

Let us proceed to calculate the quantitative effect of Wernicke's Law and the spondee zeugma and the frequency of C$\breve{V}$C in prepositives on the distribution of monosyllable types in position 8. As we saw above, for two properties x and y, the joint probability of both x and y, $f(x, y)$, is equal to the product of the simple probability of x, $f(x)$, and the conditional probability from x to y, $f_x(y)$. Therefore $f(x, y) = f(x)f_x(y)$. Dividing both sides of this equation by $f(x)$, we see that the conditional probability from x to y is equal to the joint probability of x and y divided by the simple probability of x: $f_x(y) = f(x, y)/f(x)$. Now the frequency of monosyllables (of all kinds) in any position (metrical or not) is simply the sum of the frequencies of prepositives, $f(\text{pre})$, and nonprepositives, $f(\sim\text{pre})$, in that position: $f(\text{mono}) = f(\text{pre}) + f(\sim\text{pre})$. Similarly, for the conditional probability, "if monosyllable, then C$\check{\text{V}}$C": $f_{\text{mono}}(\text{C}\check{\text{V}}\text{C}) = f_{\text{pre}}(\text{C}\check{\text{V}}\text{C}) + f_{\sim\text{pre}}(\text{C}\check{\text{V}}\text{C})$. And for the joint probability of both monosyllable and C$\check{\text{V}}$C: $f(\text{mono, C}\check{\text{V}}\text{C}) = f(\text{pre, C}\check{\text{V}}\text{C}) + f(\sim\text{pre, C}\check{\text{V}}\text{C})$. Since by the above rule for conditional probability, the frequency of C$\check{\text{V}}$C in monosyllables in position 8 equals the joint probability of both monosyllable and C$\check{\text{V}}$C in position 8 divided by the simple probability of a monosyllable in position 8, we have:

$$f_{8\text{mono}}(\text{C}\check{\text{V}}\text{C}) = \frac{f_8(\text{mono, C}\check{\text{V}}\text{C})}{f_8(\text{mono})}\,.$$

Substituting the sums above in the right-hand side of this equation, we get:

$$f_{8\text{mono}}(\text{C}\check{\text{V}}\text{C}) = \frac{f_8(\text{pre})f_{8\text{pre}}(\text{C}\check{\text{V}}\text{C}) + f_8(\sim\text{pre})f_{8\sim\text{pre}}(\text{C}\check{\text{V}}\text{C})}{f_8(\text{pre}) + f_8(\sim\text{pre})}\,.$$

We can now see precisely how Wernicke's Law and the spondee zeugma affect the frequency of C$\check{\text{V}}$C in monosyllables in position 8. The spondee zeugma insures that $f_8(\sim\text{pre})$ is very small, but most importantly Wernicke's Law guarantees that $f_{8\sim\text{pre}}(\text{C}\check{\text{V}}\text{C}) = 0$, i.e., it removes all C$\check{\text{V}}$C's from the nonprepositives. Since Wernicke's Law does not affect prepositives, we can equate the frequency of C$\check{\text{V}}$C in prepositives for nonmetrical language with the frequency in metrical contexts: $f_{\text{pre}}(\text{C}\check{\text{V}}\text{C}) = f_{8\text{pre}}(\text{C}\check{\text{V}}\text{C}) = 20\%$. This is the mathematical form of the assumption that no factors other than Wernicke's Law and the spondee zeugma affect the frequency of C$\check{\text{V}}$C in monosyllables. Thus we can simply ignore the second term of the numerator in the above equation (since it is zero) and substitute 20% for $f_{8\text{pre}}(\text{C}\check{\text{V}}\text{C})$:

$$f_{8\text{mono}}(\text{C}\check{\text{V}}\text{C}) = \frac{f_8(\text{pre}) \times 20\%}{f_8(\text{pre}) + f_8(\sim\text{pre})}\,.$$

Since the frequency of C$\check{\text{V}}$C in nonprepositives is much greater than in prepositives, we may view Wernicke's Law as cutting off the richest source of C$\check{\text{V}}$C monosyllables. Since $f_8(\sim\text{pre})$ is very small (because of the spondee zeugma), we shall be able to estimate quite adequately the frequency of C$\check{\text{V}}$C in monosyllables in position 8 [$f_{8\text{mono}}(\text{C}\check{\text{V}}\text{C})$] by the frequency of C$\check{\text{V}}$C in prepositives [$f_{\text{pre}}(\text{C}\check{\text{V}}\text{C})$], i.e., we can use $f_{8\text{mono}}(\text{C}\check{\text{V}}\text{C}) = 20\%$.[36]

Test of null hypothesis. We can now give an explicit mathematical formulation of the hypothesis that Wernicke's Law and the spondee zeugma are the only causes of the I-S difference. If they are not, we shall be able to ascertain the extent of their contribution.

36. This procedure is neither appreciably inaccurate in fact (since exceptions are rare) nor circular in theory. We approximate $f_{8\text{mono}}(\text{C}\check{\text{V}}\text{C})$ by $f_{\text{pre}}(\text{C}\check{\text{V}}\text{C}) = 20\%$. It is obvious that this approximation must be greater than the exact expected frequency

$$f_{\text{pre}}(\text{C}\check{\text{V}}\text{C}) > \frac{f_8(\text{pre})f_{\text{pre}}(\text{C}\check{\text{V}}\text{C})}{f_8(\text{pre}) + f_8(\sim\text{pre})}$$

when $f_8(\sim\text{pre})$ is greater than zero, i.e., when there are exceptions to the spondee zeugma. This minor inaccuracy actually works against the null hypothesis: we are in effect counting the small additional reduction in monosyllabic C$\check{\text{V}}$C frequency caused by exception to the spondee zeugma against the null hypothesis rather than in favor of it, as we would be entitled to do.

We already have the formula for monosyllables in position 8. All we have to do is extend Wernicke's Law to polysyllabic words. Since Wernicke's Law does not affect nonjunctural syllables, we do not have to make any adjustments in the conditional probability of $C\check{V}C$ in nonjunctural syllables of polysyllabic words. According to the present null hypothesis, then, the frequency of $C\check{V}C$ in nonjunctural syllables of polysyllabic words must be the same in position 8 as in position 7. Denoting nonjunctural syllables of polysyllabic words by S-, the present null hypothesis requires $f_{7S-}(C\check{V}C) = f_{8S-}(C\check{V}C)$. Indeed, if this were not so, it would mean that some other factor in addition to Wernicke's Law had been introduced (though not necessarily a durational factor). On the other hand, Wernicke's Law will eliminate all $C\check{V}C$'s from junctural syllables of polysyllabic words in position 8. We can therefore simply ignore the few junctural syllables that may occur in position 8 when we calculate the frequency of $C\check{V}C$. The spondee zeugma, however, will have a more complex effect. Since it so greatly reduces the frequency of junctural syllables in position 8, the frequency of nonjunctural syllables will have to increase, and even be greater than it is in position 7: $f_8(S\text{-}) > f_7(S\text{-})$. This means that the value of $f_8(S\text{-})$ in the test below will be estimated directly from a large sample of the *biceps*, since there is no a priori way to derive this value from $f_7(S\text{-})$. By the above rule for joint probabilities, the frequency of nonjunctural syllables of polysyllabic words with $C\check{V}C$ structure required by the present null hypothesis equals the frequency of nonjunctural syllables of polysyllabic words in position 8 multiplied by the frequency of $C\check{V}C$ in nonjunctural syllables of polysyllabic words (as observed in position 7): $f_8(S\text{-}, C\check{V}C) = f_8(S\text{-})f_{7S-}(C\check{V}C)$. [Note that *ex hypothesi* $f_{7S-}(C\check{V}C) = f_{8S-}(C\check{V}C)$.] Similarly the frequency of prepositives having $C\check{V}C$ structure in position 8 will be the product of the frequency of prepositives in position 8 and the frequency of $C\check{V}C$ in prepositives: $f_8(\text{pre}, C\check{V}C) = f_8(\text{pre})f_{\text{pre}}(C\check{V}C)$. Now since prepositives and nonjunctural syllables of polysyllabic words are the only sources of $C\check{V}C$ syllables in position 8, the overall frequency of $C\check{V}C$ in 8 will be (according to the null hypothesis) the sum of these two frequencies:

$$f_8'(C\check{V}C) = f_8(\text{pre})f_{\text{pre}}(C\check{V}C) + f_8(S\text{-})f_{7S-}(C\check{V}C)\,.$$

If the present null hypothesis is correct, the difference between the frequency of $C\check{V}C$ actually observed in positions 7 and 8 must be equal to the difference between the actually observed value in position 7 and the value calculated for position 8 by the above formula. Denoting the actually observed difference as Δ, and the hypothetically projected difference as Δ', we have in formulas:

$$\Delta = f_7(C\check{V}C) - f_8(C\check{V}C)$$

$$\Delta' = f_7(C\check{V}C) - [f_8(\text{pre})f_{\text{pre}}(C\check{V}C) + f_8(S\text{-})f_{7S-}(C\check{V}C)]\,.$$

If the values of Δ and Δ' are not significantly different, then it will be clear that Wernicke's Law and the spondee zeugma alone produce the I-S difference, and there will be no basis for positing any additional factors. If Δ' is smaller than Δ, then there must be some other factor involved as well.

In order to put this test into practice, we must obtain a large sample of spondaic fourth feet from Homer, and determine the following data from that sample: (a) the overall frequencies of $C\check{V}C$ in positions 7 and 8 [$f_7(C\check{V}C)$ and $f_8(C\check{V}C)$]; (b) in position 7 the frequency of $C\check{V}C$ in nonjunctural syllables of polysyllabic words [$f_{7S-}(C\check{V}C)$]; and (c) in position 8 the frequency of prepositives [$f_8(\text{pre})$] and the frequency of nonjunctural syllables of polysyllabic words [$f_8(S\text{-})$]. Using those values we then calculate Δ and Δ'. We have carried out all of this sampling for the first thousand lines of the *Iliad* and the first thousand lines of the *Odyssey*. We obtained an actual difference $\Delta = 20.91\%$. The value projected on the present null hypothesis for this sample was $\Delta' = 6.44\%$. Since the actually observed difference is more than three times as great as the hypothetically projected difference, it is clear that Wernicke's Law and the spondee zeugma cannot be the only factors producing the I-S difference. A closer examination of the data will reveal where the additional factors must lie.

We know from the spondee zeugma that nonjunctural syllables must be more frequent in position 8 than in 7: $f_8(\text{S-}) > f_7(\text{S-})$. In fact the frequency is 83.46% in position 8 (monosyllables 17.47% plus nonjunctural syllables of polysyllabic words 65.99%) as against 53.51% in position 7. We could obtain the observed difference $f_7(\text{C}\check{\text{V}}\text{C}) - f_8(\text{C}\check{\text{V}}\text{C}) = 20.91\%$ from the above formula for Δ' only if the frequency of either monosyllables or junctural syllables, or both, was greater than the frequency actually observed in position 8. For example, if we hold the frequency of monosyllables as observed, and solve the system of equations

$$20.91\% = f_7(\text{C}\check{\text{V}}\text{C}) - [f_8(\text{pre})f_{\text{pre}}(\text{C}\check{\text{V}}\text{C}) + f_8(\text{S-})f_{7\text{S-}}(\text{C}\check{\text{V}}\text{C})]$$

and

$$100\% = f_8(\text{pre}) + f_8(\text{S-}) + f_8(\text{S\#})$$

for the frequency of junctural syllables [$f_8(\text{S\#})$] that would give the observed difference of 20.91%, we obtain $f_8(\text{S\#}) = 45.78\%$ (i.e., junctural syllables in position 8 would have to increase in frequency to a degree inconsistent with the spondee zeugma). Or, keeping the junctural syllables as observed, if we solve for the frequency of prepositives, we obtain $f_8(\text{pre}) = 66.55\%$ (a degree of increase inconsistent with the resources of the language). As the facts stand, the frequency of nonjunctural syllables of polysyllabic words is greater in position 8 than in position 7: $f_8(\text{S-}) = 65.99\%$ and $f_7(\text{S-}) = 46.02\%$; yet the frequency of C$\check{\text{V}}$C in nonjunctural syllables of polysyllabic words is less in position 8 than in position 7: $f_8(\text{C}\check{\text{V}}\text{C-}) = 17.94\%$ and $f_7(\text{C}\check{\text{V}}\text{C-}) = 22.78\%$. As a result it is necessarily the case that nonjunctural syllables of polysyllabic words must have a lower frequency of C$\check{\text{V}}$C in position 8 than they do in position 7. This means that the crucial assumption of the present hypothesis that $f_{7\text{S-}}(\text{C}\check{\text{V}}\text{C}) = f_{8\text{S-}}(\text{C}\check{\text{V}}\text{C})$ is clearly false. In fact the observed figures are $f_{8\text{S-}}(\text{C}\check{\text{V}}\text{C}) = 27.19\%$ and $f_{7\text{S-}}(\text{C}\check{\text{V}}\text{C}) = 49.49\%$.

We must now determine whether this difference is metrically significant in Irigoin's sense, i.e., whether it indicates a durationally motivated choice of more C$\check{\text{V}}$C's in position 7 than in position 8. For, as we shall see in the next section, simply having proved the existence of this difference in C$\check{\text{V}}$C frequency of nonjunctural syllables between the two positions does not determine whether or not it is an automatic reflex of other factors which are not durationally motivated.

8. SOME FALSE ASSUMPTIONS

Although Irigoin is never very explicit on the matter, one suspects that underlying his claim that the I-S differences possess metrical significance is the assumption that, if Homer were writing according to the traditional conception of the hexameter (without the structural modifications Irigoin suggests), there would be no I-S difference at all between *longum* and *biceps*. But this assumption in turn presupposes one of two other assumptions: either (1) that the distribution of C$\check{\text{V}}$C, C$\bar{\text{V}}$, etc., is the same for all heavy syllables in all word shapes; or (2) that the distribution of word shapes in the hexameter is random. Since both of these assumptions are not merely theoretically questionable, but actually false, it is clear that proof of the metrical significance of the I-S differences depends on the demonstration that they are not an automatic reflex of the linguistic and metrical distribution factors just mentioned, although, as will become apparent in the next section, the full range of possibilities is not exhausted by the outline just given. The plain fact is that the mere existence of I-S differences does not guarantee their metrical significance. Any quantitative relation between *longum* and *biceps* could be the automatic outcome of the interaction of independent quantitative properties of language and meter, and thus not the result of deliberate manipulation by the poet to satisfy additional (durational) requirements. Therefore the very absence of any such difference (no I-S difference) could be of great significance for metrical structure. The absence of an I-S difference might well not be a simple reflex phenomenon (as the data given in § 10 will show). Indeed, the absence of an I-S difference would be strong indication that the contracted *biceps* was shorter than the *longum*, and definitely not that *biceps* and *longum* were equivalent (as Irigoin would apparently have assumed in that case).

9. LOGICAL PREREQUISITES FOR METRICAL SIGNIFICANCE OF DATA

The assumption that the I-S differences are metrically significant presupposes that, if the durational motivation for those differences were absent, as the linguistic structure of Homeric Greek interacted with the well-known rules of the hexameter, the various types of heavy syllable would have had equal chances of appearing in both *longum* and *biceps*, and that therefore no difference in the frequencies would be expected; or it presupposes either that the *biceps* would be biased in favor of the "shorter" types, or the *longum* in favor of the "longer" types, or both, so that the expected difference would be the reverse of the observed difference. There are two factors involved in the above assumptions concerning the interaction of language and meter. The first is a metrical one, *provenance*, the frequencies with which the syllables of the *longum* and the *biceps* respectively come from various positions in different word shapes: for example, the percentage of the *longa* that are implemented by, say, the second syllable of words of the shape ⏑ – – –, and so forth, in position 7; and the percentage of the *bicipitia* that are implemented by the third syllable of words of the shape ⏑ – – – ⏑, and so forth, in position 8. (In other words, we must know the frequency of #⏑ $\overset{7}{-}$ – –# and the frequency of #⏑ – $\overset{8}{-}$ – ⏑#, etc., in the hexameter.) The second factor is a linguistic one, *positional frequency*, the frequencies of the syllable types (CV̆C, CV̄, CV̄C) in those positions of those word shapes: for example, the frequency of CV̆C in the second syllable of words of the shape ⏑ – – –, and so on. The fundamental question is, Are the factors of provenance and positional frequency constant for all metrical locations and all positions in all word shapes or do they show variation? In other words, does a given provenance have the same frequency in both *longum* and *biceps* (e.g., is $\overset{7}{-}$ – as frequent as $\overset{8}{-}$ –, etc.) and does, say, CV̆C have the same frequency in every position of every word shape (e.g., in the language is ⏑ CV̆C – – as frequent as ⏑ – CV̆C –, and so on)? There are four combinations of constancy (+) and variation (−) of these two factors and three sorts of relation between *biceps* and *longum* that would result (in the absence of durational requirements): (a) no difference would result between the *biceps* and the *longum* (denoted by 0); (b) the resultant difference is in the same direction as the observed I-S difference (denoted >); (c) the resultant difference is in the reverse direction (denoted <). The possible combinations of constancy and variation and the resultant difference between *biceps* and *longum* for each combination are given in Table 4.

It will be seen that cases 1, 2, 3, 4(a), and 4(c) all satisfy Irigoin's underlying assumption that the I-S differences are due to a metrical rule of the structure of the hexameter which distinguishes the linguistic implementations of the *longum* and *biceps* elements. The first three cases are automatically determined as to the resultant difference: the presence of a plus value in either of the first two columns insures that no difference between the *biceps* and *longum* would arise in the absence of deliberate manipulation by the poet. The fourth, however, is not predictable in the absence of concrete data: any of the three relations of *biceps* to *longum* is logically possible. We know, however, as the statistics of O'Neill[37] show, that there are severe restrictions on the occurrence of word shapes vis-à-vis the metrical positions permitted them by the mere dactyl/spondee sequences of the hexameter. These restrictions are the result of a small set of rules, which are, of course, *not* motivated by a desire to produce I-S differences, but are totally independent factors.[38] The result of word-shape localization is that the syllables which implement the *longum* generally come from different word shapes than do syllables which implement the contracted *biceps*. It follows that any of the cases in Table 4 which show a plus in the first column must be false. Furthermore, there is absolutely no justification for assuming a priori that in the language the various syllable types must have the same frequencies in all positions in all words. Indeed, considerations of inflectional and derivational morphology would lead us to expect the opposite. We are left with the task

TABLE 4

	Provenance	Positional frequency	Difference between *biceps* and *longum*
Case 1	+	+	0
Case 2	+	−	0
Case 3	−	+	0
Case 4	−	−	(a) 0 (b) > (c) <

37. O'Neill, "Localization of Metrical Word Types."
38. See now R. Beekes, "On the Structure of the Greek Hexameter," *Glotta* 50 (1972): 1–10.

of deciding among the three logical possibilities under case 4, namely (a), (b), or (c); we obviously cannot simply assume the validity of (a) or (c), as Irigoin apparently does.

10. TEST OF NULL HYPOTHESIS: ESTIMATION OF I-S DIFFERENCE FROM PROSE

We now have a much more sophisticated null hypothesis, namely that the I-S differences arise automatically from the combination of factors: provenance and positional frequency as well as Wernicke's Law and the spondee zeugma (i.e., case 4[b] in § 9). To decide among the three alternatives of case 4, we must find a way to calculate the respective differences between the *longum* and the *biceps* for the frequencies of CV̆C, CV̄, and CV̄C that would be expected in the absence of any durational motivation. We have already isolated the metrical and linguistic factors involved. Since the former (the provenance frequencies including those affected by the spondee zeugma) can easily be calculated from data already provided by O'Neill, all we have to do is estimate the latter (positional frequencies of the syllable types) on the basis of samples from nonmetrical texts. It would be fallacious to use any metrical text. The data derived from a metrical context would contain a *petitio principii*, since one of the things we must ascertain is whether the positional frequencies in metrical contexts differ from those in prose.

Let us examine the procedure in greater detail. First of all the metrical factors: the modification for Wernicke's Law is the same as in § 7, i.e., the frequency of CV̆C for junctural syllables in position 8 is zero [$f_{8\mathrm{S}\#}(\mathrm{C\breve{V}C}) = 0$]. The new element that we have introduced is provenance, the frequency with which the *longum* or the *biceps* respectively is filled by a given syllabic position in a given word shape. For example, let us take the shape ⏑ – – –. What we have to do is convert the data given by O'Neill into percentages, so that we have the relative frequency of the *longa* that are implemented by the second syllable of this shape and the relative frequency of *bicipitia* implemented by the third syllable of this shape (i.e., the number of occurrences of ⏑ $\overset{7}{–}$ $\overset{8}{–}$ ⏑ in our sample, divided by the number of *longa* and divided by the number of contracted *bicipitia*, respectively). In the same way we obtain the provenance frequencies for each relevant syllabic position in each word shape for *longum* and *biceps*. The linguistic factor, positional frequency of syllable types, is only slightly more complex, but involves very extensive sampling from prose. To take the word shape ⏑ – – – as an example again, we obtain a large sample of words of this shape from prose, and from that sample calculate, for example, the frequency of CV̆C in the second syllabic position and in the third (since these are the only two relevant positions in that shape). We then multiply the provenance frequency of the second syllabic position in the shape ⏑ – – – by the positional frequency of CV̆C in that second position. This product is the contribution of that one provenance, ⏑ $\overset{\downarrow}{–}$ – –, to the overall frequency of CV̆C in the *longum* (and similarly for the *biceps*). Adding up all the products for each provenance and positional frequency, we calculate the overall frequency of CV̆C in the *longum* and *biceps*, respectively, that would arise in the absence of any durational factor. These frequencies are calculated in a purely mathematical way, without adopting the dubious procedure of writing hexameters by fitting together words taken at random from prose. We are using the quantitative properties of Homer's hexameter (as determined by O'Neill) and the quantitative properties of Greek linguistic structure (as determined by us from large samples of Thucydides) to make a mathematical model of the spondaic fourth foot of a hexameter in which any durational differences between heavy syllable types would be ignored. *In this way we let Homer arrange the words to fit the meter, but let Thucydides (our prose sample) provide the types of heavy syllables in those words.*

Let us introduce some abbreviatory notation at this point and proceed somewhat more rigorously. We can label each provenance with an arbitrary number: 1, 2, 3, . . . Let i stand for any one of these provenances. Similarly let j stand for one of the syllable types, C$\breve{\text{V}}$C, C$\bar{\text{V}}$, C$\bar{\text{V}}$C. Now $f_7(i)$ means the frequency with which position 7 is filled by a syllable of provenance i, e.g., the second syllable of the shape ⏑ – – –. $f'_i(j)$ means the frequency of syllable type j when its provenance is i, e.g., the frequency of C$\breve{\text{V}}$C in the second syllable of ⏑ – – –. We use the prime sign $'$ to indicate that these (positional) values are prose values as demanded by our null hypothesis, and values not directly observed in Homer. If duration really were a factor, the values of the syllable-type frequencies of each provenance obtained from metrical contexts would be different from the values obtained from the prose sample, e.g., $f_{7i}(\text{C}\breve{\text{V}}\text{C}) > f'_i(\text{C}\breve{\text{V}}\text{C}) > f_{8i}(\text{C}\breve{\text{V}}\text{C})$. Now each provenance frequency [e.g., $f_7(i)$] and each corresponding positional frequency [$f'_i(j)$] are simple and conditional probabilities respectively, so that their product is a joint probability [e.g., $f'_7(i, j)$]. For example, from Table 7 below we find that C$\breve{\text{V}}$C syllables from the second syllabic position of words with the shape ⏑ – – – constitute 7.82% of all the syllables in position 7 (according to the null hypothesis). For the sake of this example, letting i denote ⏑ $\overset{\downarrow}{–}$ – – and j denote C$\breve{\text{V}}$C, we have $f_7(i, j) = 7.82\%$ (and so on, for all the provenances and syllable types i and j can refer to, respectively, for *longum* and *biceps*). Now if we add up each of these joint probabilities [$f_7(i, j)$] for each provenance (i = 1, 2, 3, . . .) in the *longum*, we obtain the simple probability of syllable type j in the *longum:*

$$f'_7(j) = f'_7(1, j) + f'_7(2, j) + f'_7(3, j) + \ldots.$$

Such a sum of items labeled by i is indicated by $\sum_i$. Thus the frequency of syllable type j in the *longum*, expressed as the sum of the products of the provenance and positional frequencies, is

$$f'_7(j) = \sum_i f_7(i) f'_i(j)$$

and similarly for the *biceps*. The values calculated by these formulas will be the syllable-type frequencies that would occur in the *longum* and *biceps* in the absence of any durational factor in choosing between the syllable types. In other words, we are calculating the frequencies that $C\breve{V}C$, etc., would have in the *longum* and the *biceps* if each type of heavy syllable were free to occur at the prose frequency normal for it in a given syllabic position in a given word shape, i.e., if the structure of heavy syllables were (except for Wernicke's Law) irrelevant for the meter. Of course, when we take the sum over all the syllable types j as well, we have 100% of all the syllables in position 7:

$$\sum_i \sum_j f_7(i) f_i'(j) = 100\% .$$

For the contracted *biceps* we must remember the earlier remarks on Wernicke's Law, that the positional frequency of $C\breve{V}C$ is zero when the provenance is junctural in position 8: $f_{8S\#}(C\breve{V}C) = 0$, and that for monosyllables the frequency is nearly that of prepositives: $f_{8\mathrm{mono}}(C\breve{V}C) = f_{\mathrm{pre}}(C\breve{V}C)$. It should be noted that in all other cases the prose-language values of the $f_i'(j)$ will appear in the formulas for both positions 7 and 8 (this in contrast to the procedure in § 7).

If we can project, on the basis of our prose frequency values, that $f_7'(C\breve{V}C) > f_8'(C\breve{V}C)$ and $f_8'(C\bar{V}[C]) > f_7'(C\bar{V}[C])$[39] as well as that $f_7'(C\breve{V}C\text{-}) > f_8'(C\breve{V}C\text{-})$,[40] i.e., that the frequency of $C\breve{V}C$ in nonjunctural syllables in 7 is greater than in 8, then we will have demonstrated that 4(b) of Table 4 is the case and that the I-S differences are merely reflex phenomena. Any other result would be in favor of Irigoin's hypothesis.

Obviously there is no Homeric prose available for sampling; an investigation is thus at the mercy of the many possible differences of dialect, style, subject matter, etc., between Homeric language and any later Greek prose text. We are, therefore, reduced to assessing the extent to which accessible data substantiate Irigoin's hypothesis and the null hypothesis, respectively. Against Irigoin's hypothesis is the fact that it involves a complex and unnatural metrical structure. If it can further be demonstrated that, in the linguistic material of another Greek text or texts, the I-S differences would be automatic in the hexameter, that would be all the more reason not to abandon the traditionally accepted null hypothesis, unless the Homeric dialect should differ from that sample text in such a way that no I-S difference or a difference in the opposite direction (cases 4[a] and 4[c] in Table 4) would be automatic. However, it is quite improbable and empirically unprovable that the Homeric dialect would yield case 4(a) or 4(c), whereas a sample text would yield an automatic I-S difference (case 4[b]).

Having no Homeric prose, we chose Thucydides at random as the source

39. $f_7'(C\bar{V}[C])$ is the projected relative frequency of either $C\bar{V}$ or $C\bar{V}C$ syllables in position 7, i.e., the sum $f_7'(C\bar{V}) + f_7'(C\bar{V}C)$; this in turn is 100% minus the relative frequency of $C\breve{V}C$ in position 7: $f_7'(C\bar{V}[C]) = 100\% - f_7'(C\breve{V}C)$.

40. This further stipulation is necessary in view of our remarks here and in § 7 and § 9. It requires that the normal prose positional frequencies of $C\breve{V}C$ which are not affected by Wernicke's Law be greater for the provenances permitted in position 7 than for those permitted in position 8, even though the frequency of the nonjunctural provenances in 7 is smaller than in 8.

of our samples of each relevant word shape. It is on the basis of these samples that we have estimated the values of the relevant positional frequencies [the values of $f'_i(j)$ in the above formulas]. Since it is practically impossible to assess all the factors of style, subject matter, dialect, etc., there are no sure and complete criteria available on which to prefer one text over another (except, of course, length). In view of this, we do not consider it worthwhile to attempt to assess the proximity of possible sample texts to the linguistic material available to Homer with respect to all of the variables. Our aim is merely to discover whether Irigoin's presuppositions would hold for the language of a randomly chosen Greek text.

As in § 7, we need carry out our calculations only for the frequencies of C$\check{V}$C in spondees. In accordance with the distinctions imposed by Wernicke's Law, we shall present the data separately for the three major provenance classes: monosyllables, junctural syllables of polysyllabic words, and nonjunctural syllables of polysyllabic words. The observed values are those that occur in the first thousand lines of the *Iliad* and the first thousand lines of the *Odyssey* (i.e., the same sample as chosen by O'Neill).[41] The values projected on the null hypothesis are calculated on the basis of provenance frequencies obtained from O'Neill's data and positional frequencies obtained from our samples of each relevant word shape taken from Thucydides, according to the methods described above.

The frequency of monosyllabic C$\check{V}$C is given in Table 5.

TABLE 5

	Position 7	Position 8
Observed f(mono, C$\check{V}$C)	3.28%	3.59%
Projected f'(mono, C$\check{V}$C)	2.54%	3.49%

The projected value for position 7 is based on the average for all monosyllables estimated from a sample of 500 monosyllables (excluding the article) taken from Thucydides. For position 8, see the remarks in § 7.

The frequency of junctural syllables of polysyllabic words is given in Table 6.

TABLE 6

	Position 7	Position 8
Observed f(C$\check{V}$C#)	16.54%	0.16%
Projected f'(C$\check{V}$C#)	14.69%	0.00%

The projection for position 7 is based on the average for all final syllables of polysyllabic words as estimated from a sample of 500 such finals from

41. Except that we have not excluded repeated lines.

Thucydides. An impartial composition strategy was assumed for positional lengthening, according to which, for such unmetrical sequences as -CV̆C#V-, the word ending in -CV̆C# would be modified in the sense that a word ending in CV̄C or CV̆CC, etc., would be used instead (so that a metrical sequence such as -CV̄C#V- would result) in 50% of the instances, and the word to the right of the word boundary would be modified (giving, e.g., -CV̆C#CV-) in 50% of the instances. The prose frequencies were then adjusted in accordance with this strategy. This procedure was adopted to avoid the possible circularity involved in sampling from a metrical text. This procedure is in no way biased in favor of our hypothesis: if anything, it works somewhat against it.

The projected frequency of nonjunctural syllables of polysyllabic words is given in Table 7. The columns labeled $f'_7(i, \mathrm{C\breve{V}C\text{-}})$ and $f'_8(i, \mathrm{C\breve{V}C\text{-}})$ give the projected frequency of nonjunctural CV̆C syllables for each of the labeled provenances in the columns to their left. [As explained above, this frequency is the product of the corresponding provenance and positional frequencies: $f'_7(i, \mathrm{C\breve{V}C}) = f_7(i) f'_i(\mathrm{C\breve{V}C})$, etc.] The sum of the values in each column is the overall frequency of nonjunctural CV̆C in positions 7 and 8 respectively.

The projected positional frequencies for CV̆C in each word shape [$f'_i(\mathrm{C\breve{V}C\text{-}})$] are estimated from samples ranging from 200 to 500 instances of that word shape taken from Thucydides. The relevant word shapes which are individually of very low frequency in O'Neill's data[42] are correspondingly rare in prose. Obtaining samples for each rare shape would have been prohibitively laborious (and in certain cases the entire text of Thucydides might not have been adequate). Consequently, the frequency of CV̆C in the rare shapes was estimated by the mean for the other shapes. Notice that in

TABLE 7

Provenance of 7	$f'_7(i, \mathrm{C\breve{V}C\text{-}})$	Provenance of 8	$f'_8(i, \mathrm{C\breve{V}C\text{-}})$
1. $\overset{7}{-}\ -$	1.87%	1. $\overset{8}{-}\ -$	3.23%
2. $\smile\ \overset{7}{-}\ -$	4.60%	2. $\smile\ -\ \overset{8}{-}\ -$	3.99%
3. $\smile\ \overset{7}{-}\ -\ -$	7.82%	3. $\overset{8}{-}\ -\ \smile$	6.23%
4. $\smile\ \overset{7}{-}\ -\ -\ \smile$	6.98%	4. $\smile\ -\ \overset{8}{-}\ -\ \smile$	2.68%
5. rare shapes	2.53%	5. $\overset{8}{-}\ -\ \smile\ \smile$	2.82%
		6. rare shapes	2.78%
Total projected	23.80%	Total projected	21.73%
Total observed	22.78%	Total observed	17.94%

42. Although it does not matter for this particular test, since we are comparing observed and expected values for the same lines that O'Neill used, it should be noted that O'Neill's sample is too small to provide reliable estimates for the individual frequencies of each rare shape. These would have to be combined in other sorts of tests.

fact the null hypothesis does project a lower frequency of nonjunctural $C\breve{V}C$ in position 8 than in position 7.

The projected and observed overall I-S difference is given in Table 8.

TABLE 8

	Position 7	Position 8	I-S difference
Total $f(C\breve{V}C)$ projected	41.03%	25.22%	$\Delta' = 15.81\%$
Total $f(C\breve{V}C)$ observed	42.59%	21.58%	$\Delta = 20.91\%$

The results demonstrate that, of the alternatives enumerated in Table 4, the correct one is 4(b), and that the null hypothesis should be retained.

The reader has now seen that a significant I-S difference results naturally and predictably from the interaction of the metrical structure of the hexameter with one type of Greek (Thucydidean Greek). The exact statistical significance of the discrepancy between the projected and observed I-S differences is hardly worth pursuing where so many potentially divergent factors (such as dialect, subject matter, etc.) are involved. This discrepancy results from overestimation of the frequency of $C\breve{V}C$ in nonjunctural syllables for the word shapes in position 7 and especially in position 8, underestimation for monosyllables in 7, and underestimation for junctural syllables in 7 as well. (In this last case, the reason seems to be that we have chosen the above composition strategy more for its impartiality than for its accuracy.) In fact it came as somewhat of a surprise to us that such a substantial and significant I-S difference could in fact be projected for the Homeric hexameter on the basis of an Attic text.

11. CONCLUSION: "SPONTE SUA CARMEN NUMEROS VENIEBAT AD APTOS"

If any moral can be drawn from the preceding discussion, it is that a fundamental hypothesis about metrical structure, if formulated superficially, i.e., without due regard for the distributional properties of the language and their interaction with the meter, must inevitably constitute a begging of the question. Such disregard of the *fundamentum comparationis* is all the more dangerous because, while in this case it has led to the insignificant's being interpreted as significant, it could equally well have led to the converse error.

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