HEXAMETER PATTERNS, STATISTICAL INFERENCE, AND THE HOMERIC QUESTION: AN ANALYSIS OF THE LA ROCHE DATA

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INTRODUCTION

Conjectures about the composition and authorship of the *Iliad* and *Odyssey* have accumulated in increasing numbers since antiquity. Wolf's *Prolegomena*[1] gave the process of conjecture a momentum which carried it well into the twentieth century when it received fresh impetus from Parry's demonstration of the formulaic character of epic verse.[2] The problem continues to be argued. There is a good review of the literature up to 1953 by J. A. Davison in *A Companion to Homer*.[3] Later references can be found in Lesky's article in Pauly-Wissowa[4] and in the Introduction to Parry's Collected Papers.[5]

Many of the arguments which have kept the Homeric question alive involve metre. The composition of the Greek hexameter (which is older than the epic language it helped to shape) is governed by an elaborate set of rules. Complete in itself, each line contains from 12 to 17 syllables arranged in six metrical units or feet. Each of the first five feet is either a spondee (two longs) or a dactyl (a long and two shorts); the last foot is either a spondee or a trochee (one long and one

[1] F. A. Wolf, *Prolegomena ad Homerum* (Halle 1795).

[2] M. Parry, *L'Épithète Traditionelle dans Homère* (Paris 1928); *Les Formules et la Métrique d'Homère* (Paris 1928). Translated by Adam Parry (below, note 5).

[3] J. A. Davison, "The Homeric Question" in *A Companion to Homer*, edited by A. J. B. Wace and F. H. Stubbings (London 1962) 234–66.

[4] A. Lesky, "Homeros" in *RE* (supp. 11 [1968] 687–846. See also Lesky's *A History of Greek Literature* (New York 1966) 32–41.

[5] M. Parry, *The Making of Homeric Verse*. The Collected Papers of Milman Parry, edited by Adam Parry (Oxford 1971).

short). There are thus 64 possible combinations of long and short syllables, though this number is usually reduced to 32 by treating the last foot as if it were always a spondee. Some of these patterns occur much more frequently than others, while some scarcely appear at all. The arrangement of dactyls and spondees constitutes what O'Neill called the "outer" as opposed to the "inner" metric—"the principles which govern the composition of words into verses."[6] If both the inner and the outer metric are taken into consideration the possible number of hexameter patterns comes close to half a million.[7]

Because metre is so readily quantified metrical studies would seem ideally suited to the application of probability theory. The application has seldom been made,[8] however, and arguments based on the distri-

[6] E. G. O'Neill, Jr., "Word Accents and Final Syllables in Latin Verse," *TAPA* 71 (1940) 336.

[7] Close to a million if the quantity of the final syllable is differentiated. In any given language, of course, this sum is limited by the maximum number of syllables a single word can contain. Good accounts of the Greek hexameter can be found in M. Bowra, "Metre" in *A Companion to Homer* (above, note 3) 19–25; P. Maas, *Greek Metre* translated by H. Lloyd-Jones (Oxford 1962); K. Meister, *Die homerische Kunstsprache* (Leipzig 1921). In *Griechische Verskunst* (Berlin 1921) Wilamowitz compares the structure of the Greek hexameter with that of the Latin and German. Duckworth's statistics on the outer metric in Latin hexameters (first published in *TAPA* 95 [1964] 9–65; 96 [1965] 73–95; 97 [1966] 67–113; 98 [1967] 77–150) are now in book form: G. E. Duckworth, *Vergil and Classical Hexameter Poetry* (Ann Arbor 1969), rev. by E. J. Kenney, *CR* 21 (1971) 200–203.

[8] Since the advent of the computer there has been a growing interest in the application of modern statistical methods to metrical problems. In a series of articles in the L.A.S.L.A. *revue* (Liège), N. A. Greenberg applies probability theory to problems of composition, style, and authorship of Latin hexameters in a way that brings out both the strengths and the weaknesses of statistical methods in literary studies ("Words and Syllables: Four Eclogues" [1970] no. 2, 5–49; "Metrical Expectations in the *Ars Poetica*," [1970] no. 3, 111–29; "The Hexametrical Maze," [1970] no. 4, 17–63). In the same journal R. R. Dyer ("Toward Computational Procedures in Homeric Scholarship," *revue* [1967] no. 4, 1–54) suggests ways in which the computer might be used in the study of metrical word types in Homer; and J. W. Halporn ("Reflections on Metrics by Computer," *revue* [1968] no. 2, 1–11) expresses doubt that the computer will add anything to our understanding of Homeric metre.

Probability theory was first applied to the "stylometric" analysis of Greek prose by W. C. Wake, "Sentence Length Distribution of Greek Authors" *J. Roy. Stat. Soc.* Series A cxx (1957) 331–46, cited by A. Michaelson and A. Q. Morton, "The New Stylometry: A One-Word Test of Authorship for Greek Writers," *CQ* 22 (1972) 89–102. The stylometric argument assumes that there are unconscious stylistic traits, (sentence length or the frequency of the word καί, for example) that are uniformly distributed in a way that is characteristic of the author. Departures from this distribution are measured and used as a test in "problems of authorship, integrity, and chro-

bution of hexameter patterns have for the most part been subjective and impressionistic. Our study was undertaken as an experiment in the application of probability theory to this aspect of the Homeric Question.

The four largest collections of tabulated data on the Greek hexameter are the partial analyses by O'Neill and Porter of the inner or "structural" metric and the more complete analyses of the outer metric by Ludwich and La Roche. Ludwich in 1885 tabulated by book the totals of each of the 32 patterns in the *Iliad* and *Odyssey*.[9] For comparison with Homer, he also gave statistics for a large number of other hexameter poets. His analysis was soon superseded by that of La Roche (1898–1900).[10] Unlike Ludwich, who gave only totals, La Roche listed by book and line number the occurrences in both *Iliad* and *Odyssey* of all patterns except those of five dactyls. Though he did not give the totals for individual patterns, he summarized by book the totals of lines with five, four, three, two, one, and no dactyls. In subsequent articles he gave similar treatment to Hesiod and the Homeric *Hymns*, and to Callimachus, Apollonius, and Aratus. Later he published a partial

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nology," ibid. 89. The method was used by A. Q. Morton to test the authenticity of the Pauline Epistles (A. Q. Morton and J. McLeman, *Paul the Man and the Myth* [London 1966]).

[9] A. Ludwich, *Aristarchs homerische Textkritik* (Leipzig 1884–85) vol. 2, pp. 301–26.

[10] J. La Roche, "Zahlenverhältnisse im homerischen Vers," *WS* 20 (1898) 1–69; "Untersuchungen über den Vers bei Hesiod und in den homerischen Hymnen," *WS* 20 (1898) 70–90; "Der Hexameter bei Apollonios, Aratos, und Kallimachos," *WS* 21 (1899) 161–97; "Zum Prosodie und Metrik der späteren Epiker," *WS* 22 (1900) 35–55; "Zur Verstechnik des Nonnos," *WS* 22 (1900) 194–221. La Roche's figures differ from Ludwich's chiefly because of a higher proportion of dactyls to spondees. In his editions of the *Odyssey* (Leipzig 1867–68) and the *Iliad* (Leipzig 1879–80) La Roche resolved most of the diphthongs, *αι*, *ει*, *οι*, *ευ* when they appeared in the second half of the third or fifth foot. Ludwich was more conservative, "taking a stand against the relentless war of extermination (der . . . immer schonungsloser geführte Vertilgungskampf) against traditional long syllables in the Homeric texts" (op. cit. 301). Long syllables continued to disappear from the text of Homer (in Allen's edition of the *Iliad* there are 21 fewer spondees in the first 1000 lines than there are in La Roche's) but the tide finally turned. Scholars today are not so ready to support their arguments with "a text which on preconceived principles has been corrected in an archaizing manner" (A. Hoekstra, *Homeric Modifications of Formulaic Prototypes*, [Amsterdam 1965] 30). Cf. also D. W. Pye, "Wholly Spondaic Lines in Homer," *Greece and Rome* 11 (1964) 2–6, and Maas (note 7) 6. Parry himself recommended Ludwich's "traditional text of 1889–1907" ("Homer & Homeric Sytle" in *The Making of Homeric Verse*, above, note 5) 268 n. 5.

study of seven late Greek poets, Quintus Smyrnaeus, Koluthos, Tryphiodor, Musaeus, Nikander, Oppian and Manetho, limiting his listings to one- and two-dactyl lines. Finally, he made a complete study of the first five books of Nonnus' *Dionysiaca*.

O'Neill analyzed 7152 hexameters taken from the *Iliad*, *Odyssey*, Hesiod, Aratus, Callimachus, Apollonius, and Theocritus.[11] All "metrical word types" (the pattern of long and short syllables within a single word) which occur at least once in each of the seven texts were tabulated according to their position in the line. In other tables, O'Neill gave the frequencies of dactyls and spondees in each foot; the frequencies of different word-beginnings and word-endings; and the frequencies (without regard to position) of both syllabic and quantitative groups and of individual word types. Frequencies were calculated either as percentages or as fractions of 10,000.

Porter, following Fränkel, divided the hexameter line into short metrical phrases or "cola," usually four in number.[12] He identified 12 line-types which are defined by the placement of three caesuras and the presence or absence of enjambment. Using samples of 1000 lines or less from Homer, Hesiod, four *Hymns*, and Callimachus, Porter analyzed each line both by metrical word type and by colon and presented his data (transformed to a scale of 1000) in 24 tables.

When a set of data has been tabulated in this way the reader can make rough comparisons between authors and between works. Hypotheses cannot be legitimately tested, however, without subjecting the data to further statistical treatment. In classical philology statistical treatment has generally been confined to counting instances and calculating per-

[11] E. O'Neill, Jr. "The Localization of Metrical Word Types in the Greek Hexameter," *YCS* 8 (1942) 105–78.

[12] H. N. Porter, "The Early Greek Hexameter," *YCS* 12 (1951) 3–63; H. Fränkel, "Der kallimachische und der homerische Hexameter," *GGN* (Phil-hist. Kl. 1926) 197–229, revised and reprinted as "Der homerische und der kallimachische Hexameter," in *Wege und Formen Fruhgriechischen Denkens* (Munich 1960) 100–56. Fränkel was the first to organize the "laws" governing the positions which various metrical word types could or could not occupy into a set of positive rules about the inner structure (die Binnengliederung) of the line. For Fränkel, the rhythmical units or Kola into which the line was divided were also units of meaning. Porter's colon, on the other hand, was merely "an expected sequence of syllables produced by a brief rhythmical impulse," *op. cit.* 17; 24, n. 49. The metrical laws, which, as Fränkel pointed out, are chiefly prohibitions, are summarized briefly by Maas (above, note 7) 59–65, and more fully by O'Neill (above, note 11) 160–78.

centages. Differences are pronounced "significant" or "not significant" according to the impression they make upon the author by a common-sense standard.[13] In statistics, "significance" has a technical meaning and is measured in terms of probability theory. A difference that is significant at the .05, the .01, or the .001 level is a difference that might be expected to occur by chance not oftener than once in 20, once in 100, or once in 1000 times. Levels of significance are determined by standard testing procedures.[14]

The advantages of statistical analysis are threefold. (1) It makes it possible to give a synoptic view of large bodies of data so that what is essential to the hypothesis can be readily taken in and what is non-essential or meaningless can be ignored. (2) It makes it impossible to claim as significant, differences or similarities that might be due to chance. (3) It may bring out unsuspected relations among data and lead to new and fruitful hypotheses.

A large set of numbers, even when carefully tabulated, can bewilder or mislead a reader. O'Neill (above, note 11) 129 says of his Table 35, which gives the distribution of metrical word types by author: "There are many similarities in those figures, so many, indeed, that they may outweigh the differences, although there is no method of measuring the one against the other." Actually there are a number of statistical methods for measuring similarities and differences in order to bring out the significant relationships in such a table. One is to rank the frequencies for each author according to the size of the number. A

[13] O'Neill regularly used "significant" in this sense, e.g.: "The *Odyssey* shows a higher percentage than the *Iliad* in no less than 12 types, and in all but two or three the difference is large enough to be significant," (above, note 11) 118. This kind of reasoning led him to the conclusion that "the whole inner metric of the *Odyssey* . . . is consistently different from that of the *Iliad*." (*ibid.* 172). Porter, on the other hand, found the differences between the poems "slight." The structural "evidence," he said, "strongly supports the unity, if not of authorship or of time, at least of the style of the poems," (above, note 12) 27. Thus, without operational definitions, it is possible to derive opposite conclusions from the same "evidence."

[14] The statistical concepts and procedures which are presented in this paper are widely known and are discussed in standard text books, e.g. W. J. Dixon and F. J. Massey, *Introduction to Statistical Analysis*[3] (New York 1969). Texts which we have found particularly helpful are: G. A. Ferguson, *Statistical Analysis in Psychology and Education*[2] (New York 1966); W. L. Hays, *Statistics for Psychologists* (New York 1963); S. Siegel *Non-Parametric Statistics for the Behavioral Sciences* (New York 1956). We are grateful to Dr. Alice L. Palubinskas who read the manuscript and made valuable suggestions for the treatment of the data.

measure of similarity can then be obtained by taking the differences between two sets of ranks and calculating the "Spearman rank-order correlation." A correlation can range from 1 to −1. A correlation of 1 would mean that all ranks were the same; a correlation of −1 that they were directly opposed to each other; a correlation of zero that there was no relation at all. A rank-order correlation is identified by the Greek letter rho (ρ).[15]

A more exact measure of similarity is the Pearson product-moment correlation (r). It also ranges from 1 to −1 but is calculated from the raw figures rather than their ranks.[16]

A common method for measuring the difference between samples is the "chi square test". Chi square (χ^2) indicates how much a particular frequency (e.g. the frequency of a particular metrical pattern) deviates from some standard (e.g. the frequency with which the same pattern

[15] The formula for the Spearman rank-order correlation is $\rho = 1-[6\sum d^2/(N^3-N)]$ where d is the difference between one pair of ranks and N is the number of pairs. O'Neill's Table 35 gives the frequencies of 28 metrical word types in samples taken from *Iliad*, *Odyssey*, Hesiod, Aratus, Callimachus, Apollonius, and Theocritus. In the *Iliad* and *Odyssey* the ranks of the first ten word types in the list are:

Iliad	2	1	5	7	3	4	9	8	10	6
Odyssey	3	1	5	7	2	4	9	8	10	6

If the differences between ranks are squared and summed, Spearman's formula gives a correlation of .988, $[1-(6\times 2)/(1000-10)]$. For rank order correlations see Dixon and Massey (above, note 14) 349–50.

[16] For calculating r there are several formulas that can be used, all of which give the same value. The one which we used was chosen because of suitability for computer programming. It is:

$$r = \frac{N\sum XY - \sum X \sum Y}{\sqrt{[N\sum X^2 - (\sum X)^2][N\sum Y^2 - (\sum Y)^2]}}$$

where X and Y are the numbers in each pair of scores. In O'Neill's table 35, the actual frequencies of the first ten word types for *Iliad* & *Odyssey* are:

Iliad	1175	1828	708	672	1062	928	384	393	137	679
Odyssey	1061	1816	718	593	1111	1041	356	492	124	699

Applying the formula for r to these figures gives a correlation of .989. Calculated in the same way from the other figures in O'Neill's table, the correlations are *Iliad*-Hesiod .948; *Iliad*-Aratus .845; *Iliad*-Callimachus .917; *Iliad*-Apollonius .936; *Iliad*-Theocritus .969. All of these correlations are very high, reflecting the marked similarities in the structure of Greek hexameter verse, but none is so high as the correlation between *Iliad* and *Odyssey*, which almost reaches unity.

Correlations are discussed in Dixon and Massey (above, note 14) 193–221. The formula for use in computer programming is given by Ferguson (above, note 13) 111.

appears in the *Iliad*).[17] No matter how the Homeric poems were originally composed it seems to us reasonable to expect that a difference in authorship would in some degree be reflected by differences in the distribution of metrical patterns.[18] Before drawing any inference from such differences, however, it would be necessary to determine their statistical significance. The standard procedure in such a case would be to set up the "null hypothesis"—that there are no essential differences between *Iliad* and *Odyssey* or among their separate books, and test the hypothesis systematically by criteria which distinguish the

[17] The formula for chi square is $\chi^2 = \sum (O-E)^2/E$ where O is the frequency observed in the sample and E is the frequency that would be expected if it were the same as that of the standard. The $\sum$ means that the test is exhaustive and takes in the rest of the distribution as well as the sample observed. The value of chi square is always positive and can range from zero to infinity. When there are only two items in the comparison a chi square of 3.84 indicates a difference that is significant at the .05 level; if it is 6.63 or higher the difference is significant at the .01 level.

By O'Neill's count, the frequency of the metrical word type—(one long syllable) is 1265/6920 for the *Iliad* and 1244/6851 for the *Odyssey*, (above, note 11, tables 2 and 30). Thus, for the sample observed, O is 1244 and E is $1265/6920 \times 6851$ or 1252.4; for the rest of the distribution, O is 5607 and E is 5598.6. Chi square, then, is 0.07. Calculated in the same way chi square for *Iliad*-Hesiod is 4.39, *Iliad*-Aratus 45.32, *Iliad*-Callimachus 89.39, *Iliad*-Apollonius 136.64, and *Iliad*-Theocritus 36.54.

The differences between the *Iliad* and the four Alexandrians are all highly significant; between the *Iliad* and Hesiod the difference is at the .05 level; between the *Iliad* and *Odyssey* it is negligible.

For the chi square test see Dixon and Massey (above, note 14) 237–44. Its usefulness in stylometrics is thoroughly discussed by Michaelson and Morton (above, note 8).

[18] In his later writings, Parry was emphatic that the question of authorship could not be settled by considerations of style. Though struck by "a remarkable similarity between the diction of the *Iliad* and that of the *Odyssey*," he said "we must be careful not to see in this any proof of what is usually meant by the unity of the Homeric poems. All we know is that the author or authors of these two poems faithfully maintain the tradition of bardic diction, and that is why their styles, to judge from their use of epithets, match each other in the smallest details," (above, note 5) 190. With a few exceptions, Parry's successors have not adopted the position that the poems are completely formulaic but stand closer to Parry's earlier view that it is possible to distinguish between "what is traditional and what is Homer's own creation," (ibid.) 4. Hoekstra (above, note 10) 24 stated that "it is practically out of the question that Homer's diction is wholly formulaic and traditional." Cf. also J. B. Hainsworth, *The Flexibility of the Homeric Formula* (Oxford 1968) 15–19; and A. Parry, "Have We Homer's *Iliad*?" *YCS* 20 (1966) 177–216. But even if it could be demonstrated that the poems are completely formulaic, it does not follow that the formulas were put together like the pieces in a jig-saw puzzle (to use Hainsworth's figure). They were selected and arranged by some creative process oral or written, and must reflect the genius of the author or authors who selected and arranged them.

Iliad from other hexameter poems.[19] If enough such criteria are found, the hypothesis is rejected; otherwise it is retained.

Using the three tests described above we have made a computer analysis of the La Roche data, which is the largest collection of metrical data that is currently available.[20] It seems logical to begin with the outer metric, since this supplies the background against which the patterns of cola and metrical word types are organized.[21] If the results of the study warrant, we should like to see the method extended to other criteria of metre and style.

PROCEDURE

To identify the patterns we used a numerical code in which the scansion is first written as a binary number with a dactyl represented as 0 and a spondee as 1. The six digits are then divided into two groups of three and each group converted into its corresponding octal (or decimal); see Table 1.

TABLE 1. CONVERSION OF BINARY TO OCTAL NUMBERS

000=0	100=4
001=1	101=5
010=2	110=6
011=3	111=7

[19] If a statistician is attempting to determine whether a difference between two groups is significant, he begins with the null hypothesis. This postulate assumes that in the variable being measured there is no difference between the two groups. The statistician can never "prove" that differences do or do not exist, but he can arbitrarily speak of a difference as "significant" if the probability of its occurrence by chance is very low. He may decide that he is willing to risk being wrong 5% of the time. Rejecting the null hypothesis at the .05 level of significance means that the statistician is about 95% confident in the validity of his judgment that a real difference exists between the two groups. For further discussion of the statistical testing of hypotheses see Dixon and Massey (above, note 14) 75–77.

[20] For dactyl-spondee ratios Ludwich's statistics comprise a larger number of authors, but for the distribution of single patterns they are less complete than La Roche's.

[21] The outer metric also has the advantage of greater objectivity, since once the text of a line has been established there can be no disagreement over the scansion. This is not true of the inner metric. Scholars can disagree about the definition of formula and metrical word type as well as about sentence length and how a line should be divided into cola. See Hoekstra (above, note 10) 11–16, 20–24; G. S. Kirk, "Studies in Some Technical Aspects of Homeric Style," *YCS* 20 (1966) 118–19, 83–104. Kirk said (104): "There is always the question of what a colon is." There is no question of what dactyls and spondees are.

TABLE 2. DISTRIBUTION OF PATTERNS IN EIGHT EXAMPLES OF GREEK HEXAMETER VERSE

Pattern	Iliad	Odyssey	Hesiod	Hymns	Aratus	Apollonius	Callimachus	Nonnus
01	3034	2256	403	464	208	1283	209	1068
03	174	111	29	39	43	148	20	0
05	1346	1023	170	179	60	374	68	403
07	59	50	12	12	5	1	0	0
11	648	503	108	113	73	342	26	60
13	32	24	13	6	8	40	6	0
15	200	172	37	33	10	17	1	0
17	8	5	2	8	0	0	0	0
21	2292	1820	357	332	151	1151	260	638
23	124	95	27	32	37	133	16	0
25	968	829	161	132	50	320	57	244
27	51	29	10	5	2	0	0	0
31	461	457	66	94	58	235	25	12
33	30	32	8	9	8	22	4	0
35	120	110	23	19	3	4	1	0
37	4	1	0	1	0	0	0	0
41	2207	1457	282	311	136	645	92	237
43	151	105	24	24	35	77	10	0
45	967	791	125	130	45	174	37	98
47	32	34	11	9	2	2	0	0
51	432	345	69	56	42	172	12	14
53	23	11	6	9	5	20	1	0
55	129	82	26	10	8	4	0	0
57	4	1	1	2	0	0	0	0
61	1261	996	211	144	93	449	64	0
63	78	54	11	12	17	62	7	0
65	584	478	77	59	33	109	17	0
67	19	13	6	2	1	0	0	0
71	193	176	41	46	15	41	3	0
73	7	5	4	2	3	4	0	0
75	53	41	10	10	2	3	0	0
77	2	4	0	0	0	0	0	0
Total	15693	12110	2330* (2331)	2304* (2301)	1153* (1154)	5832* (5836)	936	2774

* This number is the sum of the lines actually listed by La Roche; the number in parentheses is the total number of lines given in his tabulation.

The resulting two digit number not only names the pattern (as an arbitrary code would do) but also describes it, since it can be readily translated back into the scansion pattern. The patterns range from 01 for five dactyls to 77 for six spondees. (The last foot is always treated as a spondee.)[22]

The occurrences of each of the 32 patterns were counted and the totals tabulated for each book and for each work as a whole. The Catalogue of Ships in *Iliad* 2 was treated as a separate book. The totals for complete works are given in Table 2.

The data were punched onto IBM cards and Fortran programs were written with instructions to:

1. Rank the pattern frequencies for each author or work and for each book or part of a work.
2. Compare the rank orders for each work and each book or part of a work with the rank orders of the patterns in the *Iliad* to obtain Spearman rank-order correlations.
3. Compare the frequencies themselves with corresponding frequencies in the *Iliad* to obtain Pearson product-moment correlations.
4. Compare the frequencies of individual patterns with corresponding frequencies in the *Iliad* to obtain chi squares.

The significance levels (the probability of chance occurrence) for the results were obtained from standard statistical tables.

RESULTS

The programs which we used made possible a large variety of comparisons among patterns and combinations of patterns. From the figures obtained in this way we have selected for presentation those

[22] F. P. Jones, "A Binary-Octal Code for Analyzing Hexameters," *TAPA* 96 (1966) 275–80. When there are only three digits in a binary number, conversion procedure is the same for the octal as for the decimal system. The code was designed for convenience in computer programming. It can be expanded to take in the inner metric by numbering the syllables in the line and listing the numbers of final syllables in all words but the last. Combined with the octal code number the list provides the computer with enough information to generate the metrical word types and denote their position in the line according to the numerical system of Maas (above, note 7) 59 or O'Neill above, note 11) 113.

which in our opinion bring out most clearly the similarities and differences among the authors.

Rank-Order Comparisons

There are 27 patterns that occur more than 10 times in the *Iliad*. They are listed in descending order of frequency in Table 3 with the corresponding ranks for the *Odyssey*, Hesiod, *Hymns*, Aratus, Apollonius, Callimachus and Nonnus.

One is immediately struck by the marked similarity in the ranks of

TABLE 3. RANK ORDER OF 27 PATTERNS

Pattern	Iliad	Odyssey	Hesiod	Hymns	Aratus	Apollonius	Callimachus	Nonnus
01	1	1	1	1	1	1	2	1
21	2	2	2	2	2	2	1	2
41	3	3	3	3	3	3	3	5
05	4	4	5	4	6	5	4	3
61	5	5	4	5	4	4	5	
25	6	6	6	6	8	7	6	4
45	7	7	7	7	9	9	7	6
11	8	8	8	8	5	6	8	7
65	9	9	9	10	14	13	11	
31	10	10	11	9	7	8	9	9
51	11	11	10	11	11	10	13	8
15	12	13	13	14	17	20	20	
71	13	12	12	12	16	16	18	
03	14	14	14	13	10	11	10	
43	15	16	17	16	13	14	14	
55	16	18	16	20.5	19	21.5	(24.5)	
23	17	17	15	15	12	12	12	
35	18	15	18	17	23	21.5	20	
63	19	19	21.5	18.5	15	15	15	
07	20	20	20	18.5	21.5	25	(24.5)	
75	21	21	23.5	20.5	25	23	(24.5)	
27	22	24	23.5	26	25	(26.5)	(24.5)	
13	23.5	25	19	25	19	17	16	
47	23.5	22	21.5	23	25	24	(24.5)	
33	25	23	25	23	19	18	17	
53	26	27	26.5	23	21.5	19	20	
67	27	26	26.5	27	27	(26.5)	(24.5)	

Parentheses indicate frequency of zero.

all the authors. Even Nonnus, who uses only nine of the available patterns uses them in much the same order of frequency as the others. The two commonest patterns, 01 (five dactyls) and 21 (four dactyls with spondee in the second foot), rank first and second respectively in every author except Callimachus. By contrast, they rank fifteenth and twelfth in the *Aeneid* whereas 35 (dactyls in first and fifth foot only), which is the commonest pattern in the *Aeneid*, ranks eighteenth in the *Iliad*.[23]

The rank-order differences between the *Iliad* and the other authors (with the exception of Nonnus) are given along with the correlation coefficients (ρ) in Table 4. The coefficients range from .991 for *Iliad-Odyssey* to .866 for *Iliad*-Callimachus.[24]

Though all of the correlations are high (well beyond the .01 level of significance) they arrange themselves in a descending order that is roughly chronological.

Product-Moment Correlations (*r*)

Product-moment correlations are given in Table 5. One of the conditions for using this test is that the frequencies must not cover too wide a range since the variability at each part of the range should be equal. The correlation between *Iliad* and Nonnus, who uses six of the seven common patterns, was calculated for the first group only. For the seven common patterns, the correlations are uniformly high and throw little light on differences in composition. Although the eleven

[23] Departures from Homeric practice in Callimachus and Nonnus are noted by Maas (above, note 7) 61–65. Some of these departures can be explained by differences in the outer metric. Maas's rule (section 99), "In Nonnus the tenth element is never monosyllabic, and the second and fourth are never monosyllabic in the same line," could be restated in terms of the outer metric: "In Nonnus there is no pattern ending in -3 or -7 or beginning with $6-$ or $7-$." The rule could be extended to patterns ending in -5 and beginning with an odd number (there are none in Nonnus and only two in Callimachus) and could be restated: "The sixth and eighth elements are never monosyllabic in the same line." The preference for the feminine caesura in Callimachus and Nonnus (Maas, section 90) seems clearly related to the increase in 3rd foot dactyls (patterns in $0-$, $2-$, $4-$, $6-$) from 85% in the *Iliad* to 92% in Callimachus and 97% in Nonnus.

[24] The formula for rho was modified in the case of tied ranks. For the modified formula and a discussion of the problem of tied ranks see Siegel (footnote 14) 207. The effect of the modification is slightly to reduce the value of rho.

TABLE 4. DIFFERENCES IN RANK ORDER OF 27 PATTERNS
Comparisons with *Iliad*

Pattern	Odyssey	Hesiod	Hymns	Aratus	Apollonius	Callimachus
01	0	0	0	0	0	−1
21	0	0	0	0	0	1
41	0	0	0	0	0	0
05	0	−1	0	−2	−1	0
61	0	1	0	1	1	0
25	0	0	0	−2	−1	0
45	0	0	0	−2	−2	0
11	0	0	0	3	2	0
65	0	0	−1	−5	−4	−2
31	0	−1	1	3	2	1
51	0	1	0	0	1	−2
15	−1	−1	−2	−5	−8	−8
71	1	1	1	−3	−3	−5
03	0	0	1	4	3	4
43	−1	−2	−1	2	1	1
55	−2	0	−4.5	−3	−5.5	−8.5
23	0	2	2	5	5	5
35	3	0	1	−5	−3.5	−2
63	0	−2.5	0.5	4	4	4
07	0	0	1.5	−1.5	−5	−4.5
75	0	−2.5	0.5	−4	−2	−3.5
27	−2	−1.5	−4	−3	−4.5	−2.5
13	−1.5	4.5	−1.5	4.5	6.5	7.5
47	1.5	2	0.5	−1.5	−0.5	−1
33	2	0	2	6	7	8
53	−1	−0.5	3	4.5	7	6
67	1	0.5	0	0	0.5	2.5
rho	.991	.984	.979	.911	.881	.866

TABLE 5. PRODUCT-MOMENT CORRELATIONS (*r*)
Comparisons with *Iliad*

	Odyssey	Hesiod	Homeric Hymns	Aratus	Apollonius	Callimachus	Nonnus	Aeneid
Number of Lines	12110	2330	2304	1153	5832	936	2774	9829
7 Common Patterns	.986*	.968*	.995*	.981*	.942*	.826†	.840†	−.676
11 Medium Patterns	.984*	.977*	.878*	.704*	.757*	.676†		
9 Rare Patterns	.894*	.570	.630	.548	.362	.284		

* Significant at .01 level.
† Significant at .05 level.

medium patterns differentiate more clearly among the six authors, the correlations are still very high, all of them reaching the .05 level of significance and all but two the .01. The nine rare patterns, however, provide what appears to be an excellent criterion. They fall into a regular descending order with intervals that are sharply differentiated; only the *Iliad-Odyssey* correlation is significant.

Chi Squares

We used the chi square test to compare the frequencies in the various authors of all patterns that could be expected to occur at least five times if the occurrences were proportional to those in the *Iliad*.[25]. A value

TABLE 6. PATTERNS WHICH SHOW SIGNIFICANT CHI SQUARES ($p \leq .05$) Compared with *Iliad* Frequencies

Odyssey (29)*	Hesiod (22)	Hymns (22)	Aratus (19)	Apollonius (27)		Callimachus (18)
03	01	03	03	01	33	01
25	05	23	05	03	35	03
31	41	31	11	05	41	11
41	71	61	23	07	43	15
71		65	25	11	45	21
		71	31	13	47	23
			41	15	53	35
			43	21	55	41
			45	23	63	45
			63	25	65	51
				27	67	55
				31	71	65
					75	71

* Numbers in parentheses indicate total number of patterns with expected frequencies greater than five.

[25] When calculating chi square for very small numbers it is customary to use the "Yates correction" in the formula. Some authorities recommend using the correction also when there is "one degree of freedom." Since we calculated chi squares for each pattern or group of patterns separately and thus had in each case only one degree of freedom we used the Yates correction throughout. The formula is modified by subtracting .5 from the absolute value of the numerator before squaring. With large numbers the effect of the correction is negligible but the effect increases as the samples become smaller. See Ferguson 207 and Hayes 585 (footnote 14).

of 3.84 indicates a difference that is significant at the .05 level and a value of 6.63 a difference that is significant at the .01 level. The number of patterns with significant chi squares ranged from 4 in Hesiod[26] to 25 in Apollonius. The data are given in Table 6.

Chi square distinguishes very well between the *Iliad* and later authors like Apollonius.[27] It is less satisfactory as a criterion for *Odyssey*, Hesiod, and the *Hymns*. The *Odyssey* has 29 patterns and Hesiod and the *Hymns* each have 22 with expected frequencies above five. Of these patterns, 24 in the *Odyssey*, 18 in Hesiod, and 16 in the *Hymns* do not differ significantly from the corresponding patterns in the *Iliad*.[28]

Besides single patterns we obtained chi squares for various combinations—the three commonest patterns, the seven commonest patterns, the first sixteen patterns, patterns ending in 1 and 5, and patterns ending in 3 and 7. The latter (spondaic lines) gives the clearest and seemingly the most meaningful criterion, which not only distinguishes the *Iliad* from later writers but from Hesiod and the *Hymns* as well. It does not distinguish the *Iliad* from the *Odyssey*, however. Chi square for *Iliad*–*Odyssey* is 2.92, for *Iliad*–Callimachus 5.60, for *Iliad*–Hesiod 18.02, for *Iliad*–*Hymns* 26.55, for *Iliad*–Apollonius 159.58, for *Iliad*–Aratus 205.23. Of these values only the first, 2.92 does not reach the .05 level of significance.[29]

[26] In the results presented here the poems of Hesiod are treated as a unit. When the three parts are compared separately with the *Iliad*, *Works and Days* shows greater differences than either the *Shield* or the *Theogony*. There are, for example, five patterns (01, 31, 35, 41, 71) with significant chi squares ($p \leq .05$) in *Works and Days* but only one in each of the others.

[27] The statement holds for La Roche's other examples from late Greek (see above, page 190), though for them he listed only three– and four–spondee lines. Quintus Smyrnaeus, for example, shows ten such patterns with expected frequencies greater than 10 (27, 33, 35, 47, 53, 55, 63, 65, 71, 75). All of them when compared with the *Iliad* have chi squares that are significant at the .01 level.

[28] For these comparisons we have taken .05 as the "critical level." Chi squares for the two commonest patterns, 01 and 21, though they distinguished Apollonius and Callimachus from the *Iliad*, failed to distinguish *Odyssey*, Aratus or the *Hymns* and only pattern 01 distinguished Hesiod ($\chi^2 \leq 6.20$).

[29] Though the chi square for Callimachus is significant at the .05 level, it seems small in comparison with the values for other examples of later Greek. The comparison is misleading, however. Of the 16 possible patterns for spondaic lines (all of which are found in both the *Iliad* and the *Odyssey*) there are only 7 in Callimachus. If the frequencies of these 7 patterns are compared with the corresponding frequencies in the *Iliad* (instead of taking all spondaic lines together) chi square is 20.78 instead of 5.60.

TABLE 7. RANK-ORDER DIFFERENCES IN TOP SIXTEEN PATTERNS
Separate Books of *Iliad* Compared with *Iliad* as a Whole

Patterns	1	2	2A	3	4	5	6	7	8	9	10	11	12
01	0	1	0	1	0	0	0	0	0	0	0	0	0
21	1	−1	1	−1	0	0	0	0	0	1	1	1	0
41	−1	0	−1	0	0	0	0	0	0	−1	−1	−1	0
05	1	0	0	0	1	0	0	0	2	0	1	1	0
61	−1	2	0	2	−1	0	1	1	−1	0	−1	−1	2
25	0	0	2	−1	0	1	−1	1	1	1	0	1	−0.5
45	0	−2	−1	−1	0	−1	0	−2	−2	2	0	−1	−1.5
11	0	2.5	2	1	2	0	0	1	2	0	0	0	1
65	0	0	−2	1.5	−1	0	0	1	−1	−3	0	0	−1
31	0	0.5	1	0.5	2	0	0	−2	−1	0.5	0	1	1
51	0	−3	−2	−3	−2	0	0	0	0.5	−0.5	0	−1	−1
15	3.5	2.5	0	2.5	2.5	4	2	0.5	2.5	1	2.5	0	2.5
71	2.5	1.5	1	3	1.5	−0.5	0	2	0	0	−1	3	−1
03	−1	−1	−1	0.5	−3	−1.5	−2	1	0.5	2	−1	0.5	2
43	−1	1	0	−2	−2	−0.5	1	−2.5	−3.5	0	−0.5	−0.5	−0.5
55	−4	−4	0	−4	0	−1.5	−1	−1	0	−3	0	−3	−3
rho	.940	.923	.968	.918	.946	.966	.982	.964	.948	.955	.982	.961	.954

Patterns	13	14	15	16	17	18	19	20	21	22	23	24
01	0	0	0	0	0	0	0	0	0	0	0	0
21	1	0	0	0	1	0	0	0	1	1	1	1
41	−1	0	0	0	−1	0	0	0	−1	−1	−1	−1
05	0	1	0	1	0	0	2.5	0	0	0	1	1
61	0	−1	0	−1	0	0	−1	1	0	1	−1	−1
25	2	3	1	0.5	1	0	−1	−1	0	−1	0	1
45	−1	−1	−1	1	−1	0	−0.5	0	0	0	0	−1
11	−1	−0.5	1	−1.5	1	0.5	0	1	0	0	0	0
65	0.5	−1.5	−1	1	−1	−0.5	0	1	0	0	0	2
31	1	0	0.5	1	0	0	0	−2	0	0	0.5	−1
51	−1.5	1	−0.5	−2	0	0.5	0	0	0.5	0	−0.5	−1
15	3	−1	1	0	2.5	−0.5	0	3.5	2	0.5	0	0
71	0.5	1.5	−1	2.5	−1	0	1	−0.5	1	−0.5	0	0
03	−2	0.5	0.5	−1	−1	0.5	−1	−1.5	−2.5	1.5	0	1
43	−1.5	−2	−0.5	−1	1	1	0.5	−1	−1	−1	1	−1
55	0	0	0	−0.5	−1.5	−1.5	−0.5	−0.5	0	−0.5	−1	0
rho	.960	.966	.990	.971	.974	.993	.984	.965	.979	.988	.990	.979

TABLE 8. RANK-ORDER DIFFERENCES IN TOP SIXTEEN PATTERNS
Separate Books of *Odyssey* Compared with *Iliad* as a Whole

Patterns	1	2	3	4	5	6	7	8	9	10	11	12
01	0	0	0	0	0	0	0	0	1	0	0	0
21	0	0	0	1	0	0	0	0	−1	0	0	0
41	0	0	0	−1	2	0	0	0	0	0	0	0
05	2	0	0	1	−1	2	0	1	1	0	0	1
61	−1	1.5	2	−1	1	−1	1	−1	−1	0	0	1
25	1	−1	0	0	−2	−1	−1	0	0	0	1	−2
45	−2	−0.5	−2	0	0.5	1	0	0	3	0	−1	1
11	0.5	2	0.5	0	−0.5	−1	1	2	−1	0.5	0	1
65	−0.5	0	2	0	0	1	−1	0	0	2	1	−2
31	3.5	−2	0	0	0	−1	0.5	−2	−2	−1.5	−1	0
51	−1	0	−2.5	0	0	0.5	−0.5	0	1	−1	0	0.5
15	−1	1.5	0	3.5	0	1	0	2	2	0	3	−0.5
71	−1	0.5	0	−1	2.5	−1.5	0.5	−1	−2	2	0.5	0.5
03	−0.5	1	0	0	−0.5	2	1	2	−1	−0.5	−0.5	2
43	0.5	1	0	−2	0.5	−0.5	−1.5	−2	0	1	−3	−1.5
55	−0.5	−4	0	−0.5	−2.5	−1.5	0	−1	0	−2.5	0	−1
rho	.961	.953	.973	.968	.965	.971	.988	.965	.959	.972	.967	.971

Patterns	13	14	15	16	17	18	19	20	21	22	23	24
01	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	1	0	0	0	1	0	0
41	0	1	0	0	0	−1	0	0	1	−1	0	0
05	1.5	−1	0	2	0	0	1	1	1	2	2	0
61	−1	0	0.5	0	0	1	−1	−1	−2	−0.5	−0.5	0
25	−0.5	0	1	1	1	1	1	1	1	−1.5	3	0
45	0	2	−1.5	−3	−1	−2	−1	−1	−1	0	−2.5	1
11	1	−1	0	1	3	0	2	1.5	1	2	2	1.5
65	1	−1	2	−1	−1	1	0	−1	−1	0	−2	−2
31	−2	0	−0.5	1	−1	−1	−2	1	0	−2	−2	−0.5
51	0	0	−1.5	−1	−1	0	0	−1.5	0	4	0	0
15	1	0	0	3	1	0.5	0	0	1	3	1.5	0
71	−1	0	0	−0.5	−1	1	0	1	−1	−0.5	−1	0
03	2	0	1.5	−1.5	2	1	0	0	0.5	−3	2	0.5
43	0	0.5	0.5	1	−0.5	−2.5	0	−1	−0.5	−2.5	−1.5	1
55	−2	−0.5	−2	−2	−1.5	0	0	0	0	−1	−1	−1.5
rho	.971	.987	.976	.949	.967	.973	.982	.982	.982	.914	.938	.984

Separate Books of Iliad *and* Odyssey

Both Spearman and Pearson correlations were obtained for comparing separate books of *Iliad* and *Odyssey* with the *Iliad* as a whole. In Tables 7 and 8 differences in pattern-rank between *Iliad* as a whole and separate books of *Iliad* and *Odyssey* are shown for the first 16 patterns. Spearman rank-order correlations are given at the foot of the columns. The correlations range from .993 for *Iliad* 18 to .914 for *Odyssey* 22. All are beyond the .01 level of significance.

Differences among separate books were investigated with the chi square test also. The only index which gave interpretable results was the patterns ending in 3 and 7 (spondaic lines), which had already distinguished the *Odyssey* from Hesiod and the *Hymns*. Values for individual books of *Iliad* and *Odyssey* are shown in Table 9. For the *Iliad* the only significant difference is in Book 2A (Catalogue of Ships) where chi square reaches 24.2.[30] In the other books, it scarcely rises above 1.

In the *Odyssey* the only book that gives a chi square for spondaic lines at the .01 level of significance is Book 11.[31] Book 15 is significant at the .05 level. For the others the values are lower on the average than for the *Iliad*.

DISCUSSION

If we start out with the null hypothesis that there is no essential difference between the pattern distribution in the *Iliad* and in any of the other Greek hexameter poems we can compare each one in turn and

[30] Differences in style between the Catalogue of Ships and the rest of the *Iliad* have often been commented on. Though closely attached to book 2 the episode seems clearly to have been composed independently and fitted into its present position at some later time. "Nous sommes ici dans la domaine du déblayage et du ravaudage," said Mazon, *Introduction à l'Iliade* (Paris 1967) 155. Cf. also Leaf and Bayfield, *The Iliad of Homer* (London 1965) 2.300; and R. H. Simpson and J. F. Lazenby, *The Catalogue of the Ships in Homer's Iliad* (Oxford 1970). The evidence of the spondaic lines is supported by that of three other patterns (01, 15 and 21) with significant chi squares. Two of them, 01 and 21, are the two commonest patterns in Homer.

[31] The authenticity of parts of Book 11 has frequently been questioned. See D. L. Page, *The Homeric Odyssey* (Oxford 1955) 21–51. W. B. Stanford, *The Odyssey of Homer* (London 1964) 1.381, accepts all of it except 565–627, which "has been much suspected since antiquity." The evidence of the spondaic lines though supported by that of pattern 41 with a chi square of 13.24, is not so strong as the evidence for *Iliad* 2A.

TABLE 9. CHI SQUARES OF PATTERNS ENDING IN 3 OR 7 (SPONDAIC LINES)
Separate Books of *Iliad* and *Odyssey* Compared with *Iliad* as a Whole

Book Number	Chi Square	Book Number	Chi Square	Book Number	Chi Square	Book Number	Chi Square
1	0.71	13	0.03	1	0.00	13	1.62
2	0 00	14	0.65	2	1.48	14	1.22
2A	24.23*	15	0.55	3	0.02	15	6.12†
3	0.00	16	1.31	4	0.29	16	0.04
4	0.89	17	0.02	5	0.01	17	0.64
5	0.01	18	0.15	6	0.69	18	0.25
6	0.76	19	0.00	7	0.27	19	0.17
7	0.17	20	3.28	8	0.99	20	1.57
8	1.22	21	1.05	9	0.06	21	0.01
9	0.22	22	1.30	10	1.17	22	0.04
10	0.00	23	0.86	11	8.24*	23	0.01
11	0.99	24	1.81	12	0.28	24	0.43
12	1.31						

* significant at .01 level.
† significant at .05 level.

reject or retain the hypothesis on the basis of the test results. There is no difficulty in rejecting it in the case of the four late authors, Aratus, Callimachus, Apollonius, and Nonnus. For Hesiod and the *Hymns*, however, the similarities with the *Iliad* are very striking. If the commoner patterns were used as the sole criterion it would be difficult to distinguish either of them. In the distribution of rare patterns, however, the correlation with the *Iliad* drops to .570 for Hesiod and .630 for the *Hymns*, neither of which is significant. There are also significant differences in the frequencies of spondaic lines. These results make it again necessary to reject the null hypothesis. (It should be noted that with correlations it is similarities that we are testing for significance; with chi squares it is differences.)

The *Odyssey* is close to Hesiod and the *Hymns* in the distribution of the common and medium patterns but in the rare patterns there is a marked difference. Where the correlations for *Iliad*–Hesiod and *Iliad*–*Hymns* fall well below significance level, the correlation for *Iliad*-*Odyssey* remains at .894, a value that is significant at the .01 level. And in the frequency of spondaic lines the *Odyssey*, unlike Hesiod and the *Hymns*, does not differ significantly from the *Iliad* ($\chi^2 = 2.92$). There are five individual patterns with significant chi squares, three of

them (25, 31, 41) at the .01 level. These differences are not evenly distributed throughout the poems, however, and can best be explained, we believe, by differences in the vocabularies of the two poems, especially differences in proper names. See D. L. Page, (above, note 31) 149; La Roche *WS* 20 (above, note 10) 5.

The similarity between *Iliad* and *Odyssey* is more than a matter of chi squares and coefficients of correlation. It is built into the metrical structure of the two poems. In Tables 7 and 8, rank orders of patterns in separate books of *Iliad* and *Odyssey* have been subtracted from corresponding rank orders for *Iliad* as a whole. There is very little difference in the two displays. If the rank differences are added arithmetically they are almost the same for the two poems, with *Iliad–Odyssey* differences a little smaller than *Iliad–Iliad*. As far, then, as the outer metric is concerned the similarities far outweigh the differences.

Statistical treatment is bound to be selective. It cannot state everything that is knowable about a body of data. It should be representative, however, and not leave out or obscure essential facts and relationships. Its purpose, in other words, is to reveal and not conceal.

We chose statistics that in our opinion would best bring out similarities and differences in pattern distribution between the *Iliad* and the *Odyssey*. The other poems were brought into the comparison since it would not suffice to prove or disprove similarity between *Iliad* and *Odyssey* if the criteria which we used did not distinguish the *Iliad* from other hexameter poems.

It is for philologists to determine what similarities and differences in style and metre make valid criteria of authorship. We have tried only to describe the conditions that must be satisfied before such criteria can legitimately be used in argument. A large body of metrical data is being assembled in machine-readable form and a full-scale analysis of both inner and outer metric will soon be possible.[32] When this has

[32] Tapes of the *Iliad* and *Odyssey*, Hesiod, *Hymns*, and Aratus now make up part of the data bank held by the American Philological Association, and other tapes are being added. Information about the tapes is kept up to date in the bimonthly news letter, *Calculi*, edited by Stephen V. F. Waite and published by the Department of Classics at Dartmouth College, Hanover, N. H. 03755. Some of the tapes have been edited to include the scansion pattern. Such a tape can be readily programmed to provide a tabulation in binary-octal notation of the kind of data used in preparing this paper

been completed, the hypothesis of single authorship can be reexamined. Until then we see no reason on statistical grounds for rejecting it.

(See F. P. Jones, "Notes on the Input for an Automatic Scansion Program" L.A.S.L.A. *revue* [1968] No. 4, 5–11.)

Since tapes, unlike published articles, can be continually corrected, revised, and expanded, a body of metrical data should ultimately be available that is not only error free but takes variant readings and conjectures into consideration. In the meantime, we believe it would be profitable to repeat our programs, substituting Ludwich's data for La Roche's in order to find out whether the significance of differences would increase or decrease with a more traditional text.