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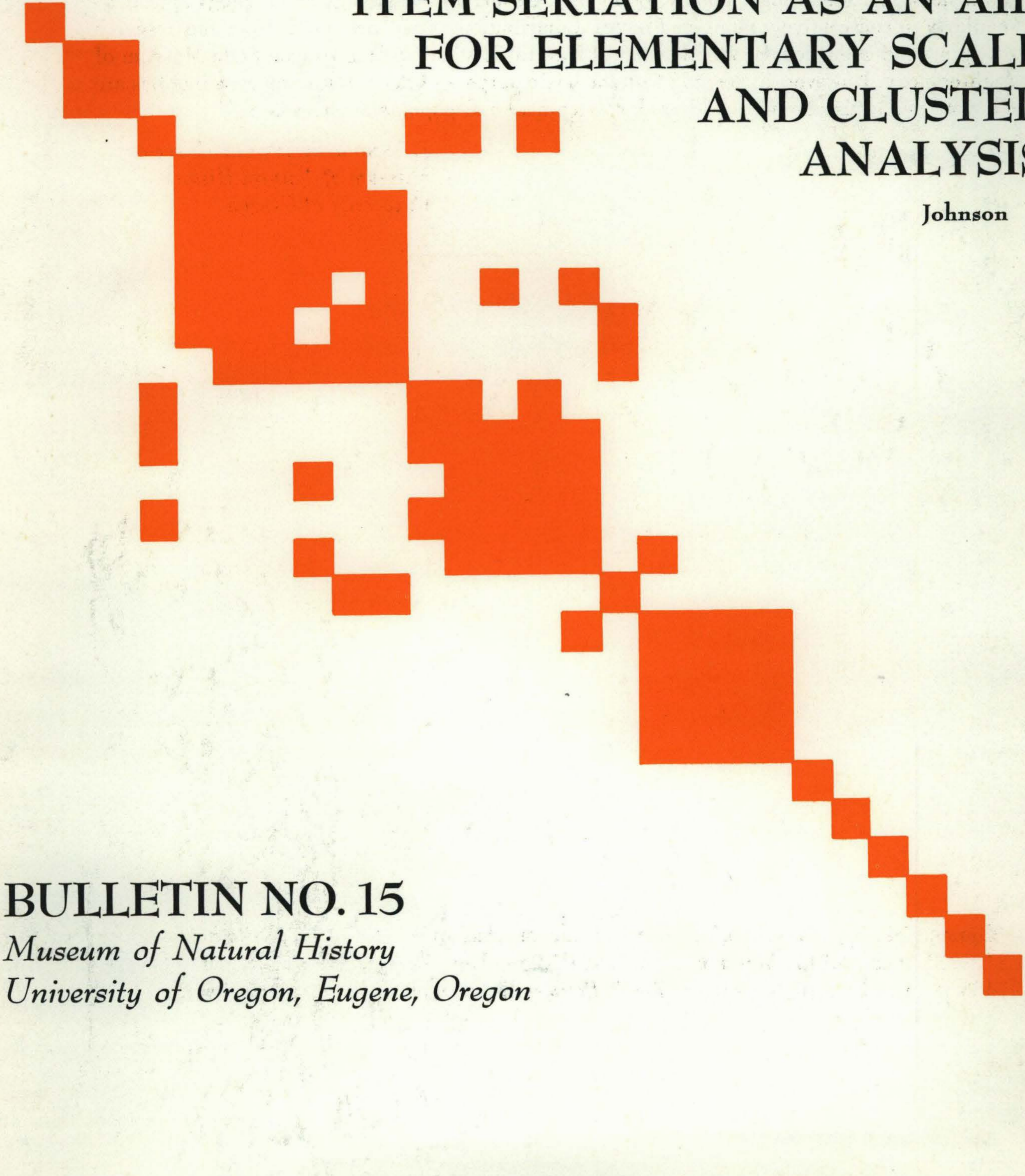
Johnson



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LeRoy Johnson, Jr.

PREFACE

Seriation has long been used as a simple technique for scaling items according to their similarities, and as a preliminary analytic step in grouping items into homogeneous units or clusters. From the 1890's onward, it has been applied sporadically and largely unsystematically. Nevertheless, the use of item seriation as a research tool has been slowly and constantly refined, especially in anthropological classification and in archaeological dating.

Not a few publications have appeared recently which treat explicity some of the problems involved in seriation, and they will be mentioned below. Several things need to be set straight, however. There is confusion in the literature about what seriation is and how it should be performed. Problems of interpretation are confused with problems of description and analysis. And the archaeological mania for estimating temporal relations between artifact assemblages has overrated the potential of item seriation for relative dating.

As I now see it, there are two basic needs which this paper may help to meet. First, seriation is a current issue, or at least a current method, particularly in the literature of anthropology and archaeology. The topic has regrettably never been given ample discussion and the need for such is self-evident. Second, seriation is a logical point at which students of biology, natural history, and social science may be introduced to the useful techniques of scale analysis and cluster analysis, to build an understanding of several of the problems involved in such studies before confronting more elegant techniques of analysis. It is hoped that the sophisticate in numerical analysis will not be impatient, then, with the following exposition, since it is addressed to research workers and students having a minimum acquaintance with numerical analysis.

The following discussion will treat seriation from several standpoints, notably (1) its basic nature, (2) its history and treatment in the literature, (3) its problems for computer processing, and (4) its proper use, particularly in conjunction with other aids, in generating overviews for bodies of numerical data.

Two previously published data sets will be used as illustrative examples: one is paleontological, the other archaeological. The former is simple and its item relations can be easily appreciated. As an illustration, therefore, it gives the reader a chance to appreciate and check, intuitively if you will, the results of the seriation study. The second data set is larger and more complex. It is given to illustrate the usefulness of item seriation for generating patterns which cannot be readily seen.

ITEM SERIATION: ITS DEFINITION

In general, the term *seriation* means the placing of items in a series so that the position of each best reflects the degree of similarity between that item and all other items in the data set. Thus seriation is one form of scale analysis. It arranges items by position alone, and does not use variation in metric distance between item positions as an expression of degree of similarity. As such it is simpler than the scaling procedures of R. N. Shepard (1962) and J. B. Kruskal (1964) which use the distance between item points to show the magnitude of the similarity between the items.

Fig. 1 illustrates three kinds of scaling models with 10 hypothetical items. Type *A* has points located in two-dimensional space, where the distances between the points indicate corresponding similarities. Type *B* is a one-dimensional scaling of items where both position and distances between points are used as measures of similarity. Type *C* presents a scale identical to *B* with the exception that metric distance between points is disregarded and position alone expresses the similarities between the items.

The use of the term *seriation* in this paper will be restricted to *C*-type series. This type may initially appear to be considerably more limited in potential than either *A* or *B*. Once they are properly seriated, however, items of *C*-type series may further be tested for clustering to produce clumps of closely similar items as illustrated in Fig. 1, D. *C*-type scaling is a simple sort, but if used in conjunction with clumping tests like those discussed later in this paper it can give information about item clustering similar to that produced by *A*- and *B*-type studies.

The *items* that are seriated in any study are a set of *individuals* scored on a set of *characters*. Seriation involves the so-called *Q*-technique when it considers the similarities between pairs of individuals (collections, assemblages, etc.) present in a population in terms of their characters (species, types, etc.), and is considered an *R*-technique study when it treats the similarities between pairs of characters present in a population (Stephenson 1953). Since seriation is applied to sample data in order to estimate population parameters, it gives data relations that can be used in inductive studies, although *sensu stricto* it is a descriptive, as opposed to an inferential, statistic.

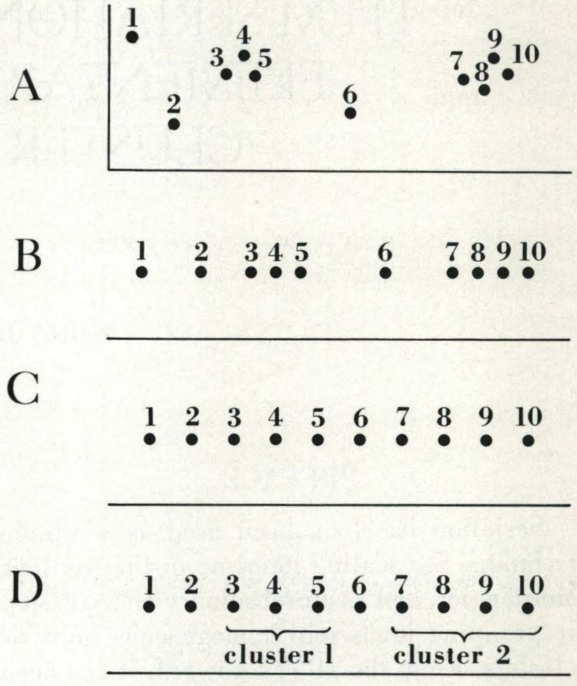

Figure 1. *Scaling Models*

Several techniques are available for seriating items. An old stand-by in archaeology is the technique of experimentally arranging artifact assemblages in such a way that the relative frequencies of various characters (usually artifact types) yield a best fit to "battleship-shaped" curves. The method has recently been restated and illustrated by the archaeologist J. A. Ford (1962), who is one of the main proponents of the method for purposes of relative dating.

Seriation can be done more systematically with similarity scores than with visual curve fitting, however. These scores are usually listed in a correlation or similarity matrix. The matrix is simply a table which contains numerical scores for all pairs of items in the set that one wishes to study. The items are listed in line along the margins of the table, horizontally and vertically, and their respective scores are given at appropriate coordinates in the table. By locating any item on one axis, and then by reading down or across to the cell in line with another item on the other axis, the similarity score between the two items can be found.

It is common practice to represent the matrix graphically in its double or symmetric form in which the upper right and lower left halves are mirror images separated by the primary diagonal of identity scores. Each half of the matrix, however, includes all the different similarity scores. If we let n represent the number of items, there are $n(n-1)/2$ different similarity scores for the $\binom{n}{2}$ pairs of items, excluding the identity scores. Fig. 2, A illustrates a double matrix of hypothetical scores, while Fig. 2, B gives the same matrix in its single form.

The actual seriation process consists of shifting the positions of the items until an arrangement is found which causes the similarity scores to fit as nearly as possible some criterion specifying score patterning in the matrix. (More will be said about the problem of shifting items through their permutations later on.) This trial manipulation of similarity scores, by shifting item positions, can be thought of as the ordering process necessary to seriate the item set properly.

The difficult thing about seriation has proved to be the definition of criteria about score patterning. Most descriptions of the model seriated matrix state either that its scores should form clusters of similar values, or that the scores should decrease gradually or continuously away from the diagonal in both directions. For example,

> . . . the resultant pattern of agreement indexes will show a definite structure, in that as any row is read from left to right [*in a double matrix*] the indexes will progressively decline from that point on . . . In other words . . . the resulting table of agreement indexes will show high values clustering about the diagonal, with decreasing values as one goes away from the diagonal either vertically or horizontally (Robinson 1951: 294-295);

> . . .the highest values, representing closest similarity, [*should*] occur nearest the diagonal axis of identity, and the remaining values decrease consistently toward the corners of the matrix opposite the diagonal (Kuzara *et al.* 1966: 1443).

ITEMS	A	B	C	D	E
A		27	25	21	8
B	27		31	24	11
C	25	31		25	12
D	21	24	25		14
E	8	11	12	14	

(A) Symmetric or Double Matrix

ITEMS	A	B	C	D	E
A		27	25	21	8
B			31	24	11
C				25	12
D					14
E					

(B) Asymmetric or Single Matrix

Figure 2. *Matrices of Hypothetical Similarity Scores*

None of these statements is precise enough to provide a usable seriation model. For example, following the above criteria, can a score two positions away from the primary diagonal be equal to a score one position away from the primary diagonal without doing violence to the model? And just how much uniformity may there be in the horizontal and vertical decrease of values as one moves away from the primary diagonal? What if the rate of decrease is marked near the diagonal but only slight or entirely nonexistent farther away from the primary diagonal? In these cases have the criteria for the model been met?

Such questions could not be answered until the nature of the seriation model itself was stated in exact terms. W. B. Craytor recently did just this. His definition of seriation is the following:

> Seriation arranges, as well as possible, a number of items into a vector array such that each item pair (except the outermost) is surrounded by less similar or equally similar item pairs (Craytor and Johnson 1968: 1, 2).

The use of Craytor's simple explanation of seriation makes it possible to define the accurately seriated item set as one whose scores satisfy a number of inequalities specified within the matrix. If we let S_{ij} represent the similarity score between items i and j, and S_{kl} the score between items k and l (where the subscripts denote the position of the items in the vector array), the inequalities requisite for the perfect seriation of any group of n items are

$$S_{ij} \geqslant S_{kl} \qquad \begin{aligned} j &= 2, 3, \ldots, n \\ i &= 1, 2, \ldots, j-1 \\ k &= 1, 2, \ldots, i \\ l &= j, j+1, \ldots, n. \end{aligned}$$

The number of these inequalities, excluding the identity scores for items with themselves, is $(n^4 + 2n^3 - 13n^2 + 10n)/24$ (for the derivation of this quantity see Craytor and Johnson 1968: 7).

It is apparent that a large number of inequalities must be satisfied by a perfectly seriated item set. Yet not all inequalities can necessarily be satisfied in given sets of empirical data. Seriation simply involves arranging the items so that their similarity scores will satisfy, *as closely as possible*, all the specified inequalities.

A BRIEF HISTORY OF SERIATION

There are two distinct lines of development for item seriation, and the two are apparently independent of one another. The earlier of the two is the application of tabular item ordering in ethnography, linguistics, physical anthropology, and archaeology and, later, in biology, mainly for item cluster-classification. The other line is represented by the development of item seriation to solve problems of chronology in archaeology.

This sketch will place most of its emphasis on the early applications of seriation in order to furnish the interested reader a background and perspective for the later seriation studies which have been reviewed adequately elsewhere. This will especially be the case in the review of works on cluster-classification. Interestingly, the latter are not always recognized as examples of seriation. Since classification *via* clustering is the goal of these studies, the fact that item seriation was a preliminary step in such classification sometimes tends to be overlooked.

ITEM CLASSIFICATION BY CLUSTERING

In the year 1895, the Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte published an article by Franz Boas titled *Indianische Sagen von der Nord-Pacifischen Küste Amerikas.* To my knowledge, this is the first use by an anthropologist of a matrix of similarity values as an aid in organizing and analyzing data. It is remarkable that Boas should have the distinction of having introduced the method since he later renounced the use of statistics in anthropology.

In this paper, Boas presented matrix tables containing the number of shared *Sagenelemente* (folktale motifs) for all pairs of 15 American ethnic groups, 12 of which belonged to the Northwest Coast culture area and three of which were located elsewhere. In compiling and organizing the tables (*ibid.*: 341-342), it appears that Boas shifted the item positions about so as to produce loose clusters of high-frequency cells along the matrix primary diagonal, thus in effect seriating the items by inspection. Among other things, Boas' interest was in comparing relationships between neighboring ethnic groups to determine, if possible, which ones were dissimilar to their neighbors and hence, by inference, recent arrivals in their area of occurrence. The Tsimshian were isolated as one such group of newcomers. This early attempt at *Q*-technique item seriation is historically important in spite of Boas' crude treatment of his frequency data—he failed to standardize his element counts correctly—and his unsystematic use of the matrix itself.

In 1908, S. A. Barrett used a tabular matrix to organize linguistic data for purposes of language classification, grouping Pomo (a California Indian language) dialects into several different kinds of speech, and showing the nearness of the dialects to each other. Eleven years later, R. B. Dixon and A. L. Kroeber's *Linguistic Families of California* (1919) combined dialects into languages within a matrix by employing the number of shared cognates as similarity scores. Similar linguistic studies followed these leads.

In 1911, J. Czekanowski published his important paper, *Objective Kriterien in der Ethnologie.* In this study he used data from Ankermann's African work to compile culture traits for 47 African ethnic groups. He calculated coefficients for a *Q*-type comparison between tribes and ordered the tribes in a double matrix to produce two areal groupings. Czekanowski considered the clusters that were discernible after seriation as particularly valuable in historical reconstruction, on the assumption that high association had historical cause. Czekanowski's technique was later used extensively in Oceanic and American studies by members of the Polish-German school of historical anthropology, and provided an impetus for similar studies by American scholars. The more recent efforts of this genre are summarized in brief but excellent form by H. E. Driver (1965: 323-328).

In the field of physical anthropology, Czekanowski early used item seriation with a tabular matrix to analyze anthropometric and other physical data. Since the accomplishments of the Polish School of physical anthropology have recently been reviewed by Czekanowski himself (1962), these studies will not be mentioned here other than to call to the reader's attention the fact that item seriation as a technique initial to clustering is still commonly used by Polish physical anthropologists (for a fairly recent example see W. Kócka 1953).

In archaeology, analyses much like Czekanowski's 1911 ethnographic study have been made to define and describe archaeological units. A. L. Kroeber (1940) tested archaeological units already reported in Tennessee (the Norris Basin complex) and in Ohio and Kentucky (the Fort Ancient aspect). To cite a more recent example, T. M. N. Lewis and M. Kneberg (1959) similarly compared a number of Archaic lithic collections from the southeastern U.S.

Quite recently, attempts have been made to define archaeological artifact types with a seriated matrix of similarity scores by Australian (Tugby 1958, 1965) and British (Clarke 1962, 1963) prehistorians. The analytic errors which they have made, which are underlined so clearly by J. Matthews (1963), have to do with facets of their studies separate from the main seriation procedures.

The foregoing illustrations are quite noticeably all anthropological, although similar matrix analyses were once common in the behavioral sciences generally. It is directly through the anthropological line, however, that the technique eveloved to the point, represented by Craytor's work cited earlier, where seriation can be used as a systematic research method.

In biology, seriation has been treated in connection with numerical taxonomy. Interestingly, R. R. Sokal and P. H. A. Sneath (1963: 176-180) clearly recognize the basic oneness of the processes used in matrix cluster analysis and in archaeological seriation for dating purposes. The taxonomist's interest, however, is in seriation for cluster-classification:

> One can . . . visualize the search for group structure as a rearranging of the rows or columns of this matrix in such a way as to obtain the optimum structure in the system. Such a proecdure has been suggested by Robinson (1951) (Sokal and Sneath 1963: 178).

A more popular and, in some ways, more detailed account of taxonomic seriation appears in a recent *Scientific American* article by R. R. Sokal (1966). An unseriated data matrix and a symmetric, seriated similarity matrix (*ibid.*: 110) show the degree of similarity between pairs of 27 individuals from seven species of nematode worms. Sokal illustrates how seriation and dendrogrammatic analysis can be used jointly to provide more information than yielded by either technique singly.

Chronology and Item Seriation

It was pointed out earlier that seriation by means of curve-fitting procedures has been part of the archaeologist's analytic tool kit for quite a while. In 1951, W. S. Robinson, a sociologist, and G. Brainerd, an archaeologist, published a matrix seriation technique that could be used to arrange artifact collections into temporal sequences. This is a kind of relative dating which allows one to say that a particular archaeological collection is earlier or later than certain other collections in the data set. The basic tenet involved is that collections which are close together in time will show similar frequencies of their respective artifact types. To measure percentage distributions, a coefficient or index of agreement was devised by Robinson (1951) to be used in the matrix as a similarity score between item pairs. This index will be discussed shortly.

Several applications of the so-called Robinson technique—seriation with *Robinson Indexes of Agreement* for relative dating—have been made with apparently good results. R. C. Belous (1953) temporally seriated a collection of archaeological sites from central California, and K. A. Dixon (1956) re-examined the Snaketown, Arizona, sequence using this method. Dixon was unable to seriate the archaeological material in terms of the chronological model, but did demonstrate the clustering tendencies of the archaeological "phases" at Snaketown.

In 1957, R. C. Troike chronologically seriated a large ceramic collection from the famous site of La Venta, Tabasco State, Mexico, with passable results, and R. E. Flanders (1960) applied the Robinson technique to a group of ceramics from Iowa. More recently, F. Hole and M. Shaw (1967) seriated west Iranian collections from the regions of Deh Luran, Khuzistan, and Khorramabad, Luristan.

The chronological seriation technique of P. Dempsey and M. Baumhoff (1963) is an outgrowth of the Robinson technique, but treats only the presence and absence of types or traits. Their method will not be described here, other than to state that there are special provisions for selecting the most desirable artifact types for chronological seriation, and for excluding other, less desirable, types. A process is provided whereby certain types can be weighted more strongly than others, to count most heavily those which are sensitive for dating purposes.

An attempt by non-archaeologists to use seriation for evolutionary or causal analyses is the study by H. E. Driver (1956; Driver and Massey 1957: 425-434) which deals with kinship terms, descent, land tenure, residence, and division of labor in American Indian societies. A possible causal sequence of forms was obtained and interpreted.

PROBLEMS OF ITEM ORDERING AND COMPUTERIZATION

Two stubborn problems face the analyst who wishes to do a seriation study. First, there is the matter of defining suitable criteria to recognize a successful seriation among several trial orderings of an item set and, second, there is the enormous amount of time necessary to rearrange the item positions by trial and error to find the best seriation of items. The two problems are not easily separated.

ORDERING CRITERIA

If different permutations of an item set are tried experimentally, it is necessary to be able to judge between them and pick out the best seriation for the set. A criterion for judgment is necessary, and several have been suggested and used.

Robinson (1951) suggests three criteria to be used in sequential stages of the seriation procedure. First, each time the item positions are rearranged along the matrix margins, the effect of the change can be measured by determining the magnitude and direction of the difference between adjacent similarity scores. This is done either in rows or columns, moving away from the diagonal in both directions (Robinson always works with the double matrix.). A negatively signed difference occurs when, of two adjacent scores, the one farther from the primary diagonal is larger than the one nearer the diagonal, and hence out of place. All signs would be positive if the similarity scores showed exactly the desired pattern.

The foregoing can produce a measure of seriation if the number of negatively signed differences is divided by the total number of differences, both positive and negative. As the proportion of negative differences decreases in trial orderings of the same data set, the better seriated the items become. This criterion, slightly modified, has been called Coefficient *A* by Kuzara *et al.* (1966: 1448). Whereas Robinson divides the number of negatively signed differences by the total differences, Kuzara, Mead, and Dixon divide by the number of similarity scores.

Another criterion of Robinson's is the patterning of the column totals of the matrix of similarity scores.

> Beginning at either end of the. . . ordered series, the totals will rise progressively to a maximum, and then will decrease progressively to a minimum at the other end of the series (Robinson 1951: 298).

The effects of item rearrangement can be seen in this pattern, and the best seriated permutation can be recognized.

A third criterion is the sum of the squares of the negatively signed differences divided by the sum of the squares of all differences, positive and negative. Using the squares of the differences in this calculation gives relatively greater importance to larger score differences. Kuzara *et al.* (1966: 1448) have titled this Matrix Coefficient *B*.

Other criteria have also been used, *e.g.*, Driver and Massey's (1957: 432-434) use of the mean of each diagonal set of scores parallel to the primary diagonal of identity. Beginning at the end farthest from the primary diagonal, the averages should rise progressively toward the diagonal which contains the identity scores. Rearrangement of item positions should eventually produce a good approximation to this pattern. Hole and Shaw (1967: 14) simply use the sum of the errors (the differences which are negative as one moves away from the diagonal) which occurs in the matrix. This criterion decreases as the trial orderings improve, zero indicating perfect seriation in terms of the ideal model.

These criteria are all biased measures of seriation and will not be considered further. They are limited either by hazy definitions of the ideal seriation model or by the fact that only relationships between adjacent similarity scores are considered. W. B. Craytor has given the most suitable definition of seriation and the most suitable ordering criterion to date (Craytor and Johnson 1968). His PROGRAM SERI-

ATE,[1] which incorporates this criterion, will be used to analyze the two data sets used as illustrations later in the paper.

Craytor's statement about the inequalities that should be met in any matrix of similarity scores, makes it possible to define a useful and logically consistent criterion for evaluating different orderings of the same data. This is called *Coefficient H* (*ibid.*: 3), and is the sum of all the score differences, that is

$$H = \sum_{j=2}^{n} \sum_{i=1}^{j-1} \sum_{k=1}^{i} \sum_{l=j}^{n} S_j^i - S_l^k$$

$$\text{for} \quad \begin{aligned} j &= 2, 3, \ldots, n \\ i &= 1, 2, \ldots, j-1 \\ k &= 1, 2, \ldots, i \\ l &= j, j+1, \ldots, n. \end{aligned}$$

Let n represent the number of items to be seriated in a given data set, S_j^i represent the similarity score between the item in row i and the item in column j in the similarity matrix, and S_l^k represent the similarity score between the item in row k and the item in column l. In the process of seriating an item group, Coefficient H would be maximized. *Note that H takes account of the magnitude of the similarity score differences and considers inequalities other than those between adjacent scores.* The degree to which inequalities are satisfied is important, since similarity scores are often imprecise. Small differences between them are commonly insignificant and may be due to sampling error.

At this point it is important to mention a major difference between Craytor's treatment of the similarity matrix and the treatment employed by most other published seriation procedures. Craytor never uses the identity scores in calculating score differences to be used in Coefficient H and Matrix Coefficient C (defined below). It was empirically demonstrated that for many data sets the major score differences were those between the identity scores and the cluding the identity differences tends to mask scores adjacent to the primary diagonal. In- the important score differences located away from the diagonal of identity. Also, there is simply no theoretical justification for their consideration.

Craytor has also invented a seriation criterion for comparing the degree of seriation between different sets of items, a job for which Coefficient H is ineffective. H is standardized into a general seriation coefficient, called *Matrix Coefficient C* (*ibid.*: 3). It is calculated by dividing Coefficient H by the number of inequalities tested, that is by $(n^4 + 2n^3 - 13n^2 + 10n)/24$, to get the average inequality difference, and then dividing by the standard deviation of the $n(n-1)/2$ similarity scores.

Matrix Coefficient C has an approximate value of zero for a randomly arranged set of items, but in general the value of C becomes larger as the matrix is more perfectly seriated. It has been empirically determined that a C-value of approximately 2 is indicative of excellent seriation; that is to say, 2 is approached as the requisite inequalities are satisfied. Both H and C will be used with the data sets analyzed later in this paper.

ITEM MANIPULATION

The experimental rearranging or manipulating of items is the second major problem in the seriation technique. This is not as simple as it may sound. Every time the position of a row is changed, the position of the corresponding column has to be changed. Such a process becomes unwieldy and time consuming when many items make up the item set. Computerization of the procedure solves the unwieldiness problem, but not the time problem.

There are $n!/2$ essentially different permutations for an item set, where n is the number of items. (Of the $n!$ permutations, those that are the reverse of the others represent the same sequence, since the direction of the permutation is unimportant.) Table 1 gives the number of essentially different permutations for the values of n below 21. Quite clearly, a prohibi-

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[1] PROGRAM SERIATE is written in FORTRAN IV for the IBM 360-Model 40 computer. A complete program listing appears in Craytor and Johnson (1968: 15*ff*).

tive amount of time would be necessary to try all these permutations except when working with very small *n*'s.

TABLE 1, No. of Essentially Different Item Permutations for Values of *n* Below 21

n	$\frac{n!}{2}$
2	1
3	3
4	12
5	60
6	360
7	2,520
8	20,160
9	181,440
10	1.82×10^{6}
11	2.00×10^{7}
12	2.40×10^{8}
13	3.12×10^{9}
14	4.36×10^{10}
15	$.66 \times 10^{12}$
16	1.04×10^{13}
17	1.78×10^{14}
18	3.20×10^{15}
19	$.61 \times 10^{17}$
20	1.22×10^{18}

Even when the analyst uses a digital computer to seriate an item set, it is feasible to try all positions of *n* with only, say, sets of 5 items or less. At least four computer programs for seriation have been written and used by American archaeologists: Ascher and Ascher (1963), Kuzara *et al.* (1966), Hole and Shaw (1967), and Craytor and Johnson (1968).

If one uses Craytor's PROGRAM SERIATE and his estimations of run time (*ibid.*: 14), 20 items would demand a minimum of 600 billion years of computer time to try all one quintillion, two-hundred twenty quadrillion essentially different permutations! It does seem that some kind of short cut has to be adopted to choose certain of the possible $n!/2$ permutations for trial orderings. It has already been decided that these tries will be compared by Craytor's Coefficient *H* and Matrix Coefficient *C* to select the best one. We can review, briefly, the short cut procedures that have been proposed and explain the one that will be used here, the one incorporated in PROGRAM SERIATE.

The Aschers' basic procedure (1963: 1046-1048) instructs the computer to insert, one at a time, each row-column of the item array (1, 2, 3, . . . , *n*), beginning with 1 and proceeding through *n*, until the full matrix for the data set is complete. Each placement decision is based on the assumption that the items already ordered are in correct position, although there is no justification for this assumption. The number of negatively signed differences between scores is used as an ordering criterion. Understandably, the Aschers note that the order of the input array can influence the final seriation markedly.

The procedure used by Kuzara *et al.* (1966: 1445-1446) is different from the above in its basic conception. It involves three stages. Stage I consists of moving row-column 1 into position 2, so that the original row-column 2 then occupies position 1; next, the original row-column 1 which is now in position 2 is moved down to position 3. The procedure is continued until row-column 1 is tried in all positions of the item array. Matrix Cofficient *A* or Matrix Coefficient *B* is used to compare the different permultaitons, and the permutation producing the best ordering coefficient is held in storage. This permutation is then used as a new starting matrix, and row-column 2 is tried in the same fashion as row-column 1 in all positions. If a particular shift in the position of row-column 2 yields a better ordering coefficient, the corresponding item permutation is held in memory. Using this permutation as a starting matrix, row-column 3 is shifted through all positions, continuing the process through the *n* items.

Stage II starts with the item permutation having the best ordering coefficient that was found in Stage I, and the whole process is repeated again. This is continued until the best ordering obtained by trying every row-column in every successive position is identical to the previous best ordering. Stage III, the last stage, repeats Stage I and II procedures, but randomizes the input array at the beginning of each Stage I action, since input order introduces a bias in this type seriation, and the employment of different input orders helps reduce this bias.

Hole and Shaw's program (1967: 16-17) specifies two short-cut techniques for trying items in different positions, which they call search patterns. The first they call pairwise interchange. First, the items which occupy the first and second positions are interchanged, and the resultant matrix evaluated by an ordering criterion (the sum of the errors, the negatively signed differences). Next, the second trial ordering interchanges the first and third positions of the matrix item array, and so on until all possible pairwise interchanges have been made and evaluated. The second technique is called successive rotation, and is apparently identical to the item manipuation process of Kuzara *et al.* (1966).

Craytor's PROGRAM SERIATE uses the item manipulation technique of Kuzara *et al.* (1966), but Craytor's decision to use it cannot be readily grasped until another matter is discussed. It is necessary to consider the relations between the ordering coefficients and their successive permutations. If a group of item permutations is plotted against the respective ordering coefficients of the items (as illustrated in Craytor and Johnson 1968: Fig. 3), where the permutations are ordered along the horizontal axis on the basis of similarity of successive arrays to all others, several local modes or maxima may result, one of which is the best. It is normally this best maximum that the analyst desires in seriating a data set.

The ideal procedure is to generate a random sequence of items and then change their positions in the item series until the permutation corresponding to the highest local maximum is found. But necessary to such a procedure is the use of some criterion to determine if a permutation corresponds to a local maximum. The item manipulation technique of Kuzara provides the needed criterion, which is therefore called *Kuzara's Criterion* (*ibid.*: 4). It works as follows.

An item permutation whose Coefficient *H* is in the close vicinity of a local maximum possesses an *H*-value greater than, or equal to, any other Coefficient *H* corresponding to the permutations that might be formed by shifting any item, but only *one item at a time*, through the positions of the item permutation being considered. Thus Kuzara's manipulation technique provides an excellent method of shifting item positions *one at a time* until good seriation is achieved, as indicated by *H*-values that must be in the vicinity of maxima of the type defined above. If the ordering procedure is repeated many times, it should be possible to approximate the absolute maximum (if, indeed, more than one maximum exists) corresponding to the best seriated permutation of the item group. Kuzara's Criterion for reaching the vicinity of the highest local degree of seriation is fulfilled by repeating the ordering attempts until the ordering coefficient for the item permutation produced by one ordering is equal to the ordering coefficient for the item permutation produced by the pass previous to it.

Each seriation of a randomly generated item sequence may be referred to as an ordering. Whether or not there is more than one local maximum for an item group can usually be determined in one ordering. If an ordering produces a nearly perfectly seriated item permutation (as would be indicated by a value of approximately 2 for Matrix Coefficient *C*), then there is very little chance of getting different or dissimilar permutations from more orderings. But a poorly seriated item permutation indicates an inherent instability within the item set, which is to say, the presence of complex and multidimensional relationships between the items. In such cases several local maxima may occur for the degrees of seriation of the different permutations.

SIMILARITY SCORES

The number of different similarity scores which could conceivably be used for item seriation is large. Some kinds of scores are much better suited for item seriation than others, and their suitability needs to be considered from two standpoints. The first has to do with the nature of score relations in the seriation matrix; the second has to do with the problem of emphasis and reliability of the raw data whence the similarity scores are derived.

The most suitable similarity scores (1) are normatized (standardized) and (2) state similarity in terms of an equal-unit scale. The prime reason for normatizing item similarity scores is to make samples of different sizes comparable for the study. The simplest way to normatize is to equate each sample n with 100 per cent and then calculate similarity scores from the resultant percentages. Normatizing is, of course, necessary when the availability samples are unequal, not when equal samples can be drawn during data collection. Availability samples, however, are commonly used in anthropologic, archaeologic, and natural-historic analyses.

It was said above that suitable similarity scores must state similarity in terms of an equal-unit scale. In concrete terms, a given difference in score size between two high-value scores must mean the same thing as the same size difference between two low-value scores. This is a necessary assumption underlying the summation of inequalities used in Craytor's Coefficient H and in Matrix Coefficient C. All the inequalities must have the same unit meaning; *e.g.*, an inequality of 8 must have twice the magnitude, in meaning, as an inequality of 4.

Most coefficients of association and correlation do not behave according to this criterion, especially measures like *Phi* which are based on Pearson's product-moment coefficient r. Values of r falling between zero and ± 1 are not easy to interpret intuitively. If one were not forewarned, he might think than an r of 0.80 was twice as good or twice as strong as an r of 0.40. But it is easily demonstrated that $100 \times r^2$ per cent of the variation of one variable is explained by differences in the other variable.[2] If $r = 0.80$, then 64 per cent of the variation of one variable is accounted for by the variation in the other. When $r = 0.40$, only 16 per cent of this type variance is accounted for. Thus an r of 0.80 is four times as strong as an r of 0.40, not twice as strong. Correlation coefficients, to be used in a matrix for item seriation, can be transformed into percentages, Fisher's z, or to angles that are the arc cosines of the correlation coefficients (for details see Sokal and Sneath 1963: 310).

Another problem is to decide whether to give equal weight to characters in the calculation of a similarity score, as in the case of correlation coefficients, or whether to weight the characters differently, for example in terms of their relative prevalence or dominance. Numerical taxonomists prefer to weight characters equally in order to minimize interpretative bias. In comparing paleontologic and archaeologic collections, however, one may wish to allow dominant (abundant) characters to influence similarity scores more strongly than rare characters. This interest in dominant characters usually reflects the kinds of inter-assemblage differences which the paleontologist or archaeologist deems important in his comparative studies.

A short digression is in order to discuss the suitability of similarity scores for individuals that represent stratigraphic and/or geographic units, since these are my special interest as an archaeologist: that is to say, individuals composed of characters that are found as objects occurring naturally in, or upon, the earth such as paleontologic collections, archaeologic assemblages, and the like. The peculiar problem that these data usually pose is that different assemblages often occur near or next to one another, as in superimposed geologic strata or depositional zones. Mixture between strata is common or even expected, often difficult to

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[2] It should be noted that r^2 and V^2 explain variation if, and only if, the data are linear and homescedastic. ϕ^2 is less instructive because of its low tolerance to marginal variation.

recognize, and needs to be accounted for in calculating similarity scores for the assemblage pairs.

W. Lipe (1964: 103, 104) makes an important observation. He points out that a similarity score that depends on presence and absence counts may not be as useful as the Robinson Index of Agreement, which is based on percentages, in instances where a few specimens from one period or assemblage have been mixed with those of another. In cases where intruded specimens occur, but are not numerous, the Robinson Index of Agreement allows them to influence the similarity score only minimally, since their corresponding percentages will be quite small.

The Robinson (1951) Index of Agreement will be used in the following data analyses for four reasons. First, it is a normatized score. Second, it employs an equal-unit scale. Third, it reduces the effect of moderate inter-assemblage mixture on the resultant similarity scores. And fourth, it gives strong weight to dominant characters in the assemblages being compared.

The Robinson Index of Agreement is calculated in this way. Each individual assemblage is set equal to 100 per cent. The percentage for each character (type, species, etc.) in each collection is calculated. Each assemblage is compared with all others in respect to the percentages of its characters. Character by character, the smaller percentage (of whichever assemblage) is subtracted from the larger, and the differences for all characters are added to provide the total difference between the assemblages. Next, this figure is subtracted from the figure 200 (100 per cent for each assemblage) to obtain a similarity score between the two assemblages. Fig. 3 illustrates this procedure and shows the areas of agreement and disagreement between two hypothetical assemblages, lots *A* and *B*.

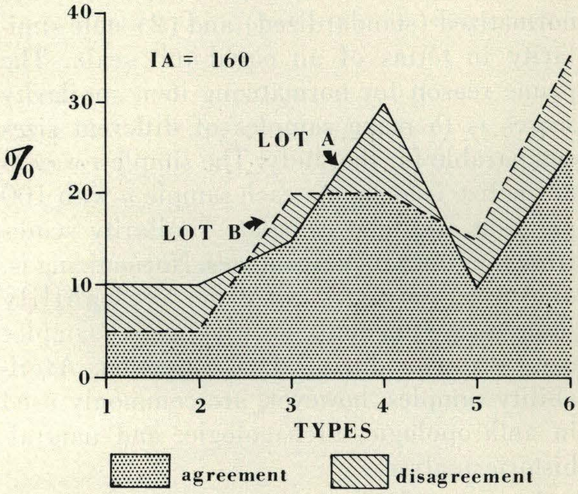


Figure 3. *Areas of Agreement and Disagreement for a Robinson Index of Agreement (IA) between Two Hypothetical Assemblages, Lots A and B*

TWO EXAMPLE DATA SETS

Two data sets will illustrate item seriation and its use with adjunct comparative techniques. The first set is 11 late Tertiary vertebrate collections which have been compared and analyzed by J. A. Shotwell (1955, 1958, 1963). The collections have been classed into community types on the basis of their constituent genera, and therefore make a fine control group for appraising the results of the present comparative approach. The data, further, are not so complex that the reader cannot grasp the major relations between faunas from the raw frequency information (*ibid.*).

The second data group is made up of 26 Upper Paleolithic archaeologic assemblages from southwestern France. Aurignacian, Perigordian, and Solutrean lithic collections are represented. D. de Sonneville-Bordes (1960) has interpreted all the assemblages with comparative methods that will be mentioned later, and P. E. Smith (1966) has recently reanalyzed the Solutrean material. This data set was selected because of its relatively large number of assemblages, because of the large number of characters in the assemblages, and because of the apparent complexity of relations between collections. In other words, this second analysis will be more difficult than that of the vertebrate data, since inter-assemblage relations cannot be discerned so easily. Therefore it is a more demanding test of item seriation.

THE LATE TERTIARY FAUNAS

The 11 vertebrate collections are assigned lot numbers in Table 2, and each lot is identified by name, sample size, and publication source. All are from eastern Oregon except lot 1, the Hemphill (Coffee Ranch) quarry collection from Texas. Shotwell's analysis (*ibid.*) had as its goal the definition of functional, ecological community types on the basis of clusters of specific animal forms which lived in the same habitat. The adaptive morphology of the community members was used to infer the habitat characters of each community.

Shotwell used a technique for community typology that involved the concept of a proximal community. Where the number of skeletal elements per individual animal was above average for the data group, Shotwell isolated these genera and species as members of the *in situ* or proximal community. Forms with only a few skeletal elements per individual were segregated and considered as intrusive into the proximal community characterizing a collection. This kind of intrusion is assumed to have occurred during the geologic period in which the collection belongs, not as a result of stratigraphic mixture.

Using this method, Shotwell classed the 11 vertebrate collections into the following community types: *pond-bank* (lots 2, 3, 4, 5, and 9), *grassland* (lots 1 and 8), *savanna* (lot 10), *woodland* (lot 7), *border*—a unique commu-

TABLE 2, KEY TO LOT IDENTIFICATION,
LATE TERTIARY FAUNAL COLLECTIONS

Lot No.	*Fauna*	*N*	*Source*
1	Hemphill	3259	Shotwell 1958: Table 2, p. 274
2	McKay Reservoir	751	Shotwell 1958: Table 2, p. 274
3	McKay small quarry sample	95	Shotwell 1958: Table 2, p. 274
4	McKay small float sample	95	Shotwell 1958: Table 2, p. 274
5	Krebs Ranch 1	91	Shotwell 1958: Table 3, p. 277
6	Krebs Ranch 2	145	Shotwell 1958: Table 3, p. 277
7	West End Blowout	549	Shotwell 1958: Table 3, p. 277
8	Boardman	676	Shotwell 1958: Table 3, p. 277
9	Black Bute Q11	97	Shotwell 1963: Table 1, p. 14
10	Black Butte Q3	220	Shotwell 1963: Table 1, p. 14
11	Otis Basin	66	Shotwell 1963: Table 2, p. 17

TABLE 3, KEY TO GENUS IDENTIFICATION

No.	*Form*
1	*Scapanus*
2	*Hydroscapheus*
3	Sloth
4	Chiropterid
5	*Hypolagus*
6	*Ochotona*
7	*Liodontia*
8	*Mylagaulus*
9	*Marmota*
10	*Citellus* (O)
11	*Citellus* (C)
12	*Pliosaccomys*
13	*Perognathus*
14	*Leptodontomys*
15	*Dipoides* and *Eucastor*
16	*Castor*
17	*Prosomys*
18	*Pliozapus*
19	*Plesiogulo*
20	*Mustela*
21	*Pliotaxidea*
22	*Osteoborus*
23	*Canis*
24	*Vulpes*
25	*Agriotherium*
26	*Felis*
27	*Machairodus*
28	*Hipparion*
29	*Neohipparion*
30	*Nannippus*
31	*Pliohippus Astrohippus*
32	*Pliohippus*
33	*Aphelops*
34	*Teleoceras*
35	*Prosthennops*
36	*Pediomeryx*
37	*Procamelus, Pliauchenia,* and "small camel"
38	*Paracamelus, Megatylopus,* and "large camel"
39	*Alticamelus*
40	*Mammut*
41	*Capromeryx*
42	*Peromyscus*
43	*Bassariscus*
44	*Sphenophalos*
45	*Hesperosorex*
46	*Cupidinomys*
47	*Hystricops*
48	*Ustatochoerus*

nity closely adjacent to several others (lot 11), and *transitional pond-bank/woodland* (lot 6). Each type was characterized by specified vertebrate forms (*e.g.,* Shotwell 1958: 282, Fig. 13).

The problem now is whether item seriation and adjunct techniques can provide information about community relations that agrees with Shotwell's findings and, if we are fortunate, perhaps provide additional information about these relationships. A *Q*-technique analysis is planned, one which compares assemblages on the basis of their genera and species. Before doing this, however, it is necessary to combine certain of Shotwell's forms from different geologic periods into comparable functional categories, since the emphasis of the study is on functional articulation within community types.

Table 3 lists the 48 vertebrate forms that were decided upon after consultation with Shotwell. Note that the two beavers, *Dipoides* and *Eucastor,* have been combined in form 15; *Procamelus, Pliauchenia,* and "small camel" in form 37; and *Paracamelus, Megatylopus,* and "large camel" in form 38.

ITEM SERIATION

The first step in the study is simple scale analysis by item seriation using Craytor's PROGRAM SERIATE, which is similarity scaling as opposed to complexity scaling. Percentages and Robinson Indexes of Agreement were calculated in standard form (Robinson 1951). These similarity scores were placed into a data matrix (Fig. 4) and the items were seriated with the IBM 360-Model 40 computer of the Statistical Laboratory and Computing Center of the University of Oregon.

The best seriation out of 10 tries produced a Coefficient *H* of 33947 and a Matrix Coefficient *C* of 1.16252. The final item array of lots is (9, 5, 2, 4, 3, 6, 7, 11, 8, 10, 1) (Fig. 5). We already know that the position of any lot in the array is a reflection of its degree of similarity to all other lots. The positioning of the

LOTS	1	2	3	4	5	6	7	8	9	10	11
1	200	14	11	9	4	17	27	68	7	51	15
2	14	200	147	163	125	83	65	30	100	7	40
3	11	147	200	157	108	96	81	31	87	6	61
4	9	163	157	200	139	83	73	29	114	4	46
5	4	125	108	139	200	65	38	7	118	0	24
6	17	83	96	83	65	200	104	35	48	11	54
7	27	65	81	73	38	104	200	49	29	43	83
8	68	30	31	29	7	35	49	200	3	78	25
9	7	100	87	114	118	48	29	3	200	2	19
10	51	7	6	4	0	11	43	78	2	200	46
11	15	40	61	46	24	54	83	25	19	46	200

Figure 4. *Data Matrix with Robinson Indexes of Agreement for 11 Late Tertiary Vertebrate Collections*

items produces an overview of relations according to the *C*-type scale illustrated earlier in Fig. 1.

If Shotwell's community types are listed by the side of each appropriate lot in the seriated array, we obtain the following pattern.

lot no.	*community type*
9	pond-bank
5	pond-bank
2	pond-bank
4	pond-bank
3	pond-bank
6	transitional pond-bank/woodland
7	woodland
11	border
8	grassland
10	savanna
1	grassland

At this point, seriation has produced an interpretable picture according to Shotwell's characterization of the lots in his published studies. Pond-bank communities fall at one end of the series, grassland and savanna communities at the other. The woodland community is in the center with the transitional and border communities where they would be expected on either side of woodland (Shotwell, personal communication, 1968).

It is now useful to see whether a gradual progression is involved in the array, or else a tendency toward the kind of clumping illustrated in Fig. 1, D. First, a great deal can be learned from the value of Matrix Coefficient *C* that belongs to the best item seriation produced by the computer. A *C*-value of 1.16252 was obtained. If an ordering produces a nearly perfectly seriated item series, that is, one that fits the stated seriation model nearly perfectly, this indicates a gradual progression in the similarity scale. This would be indicated by a value of approximately 2 for Matrix Coefficient *C*.

The value of 1.16252 is only slightly more than half the ideal *C*-value of 2. Taken by itself, this figure indicates an inherent instability within the item set and very strongly suggests the presence of clumps of comparable similarity scores. Once this much has been learned, the clumps can be discovered by additional analyses.

CLUSTER SEARCH

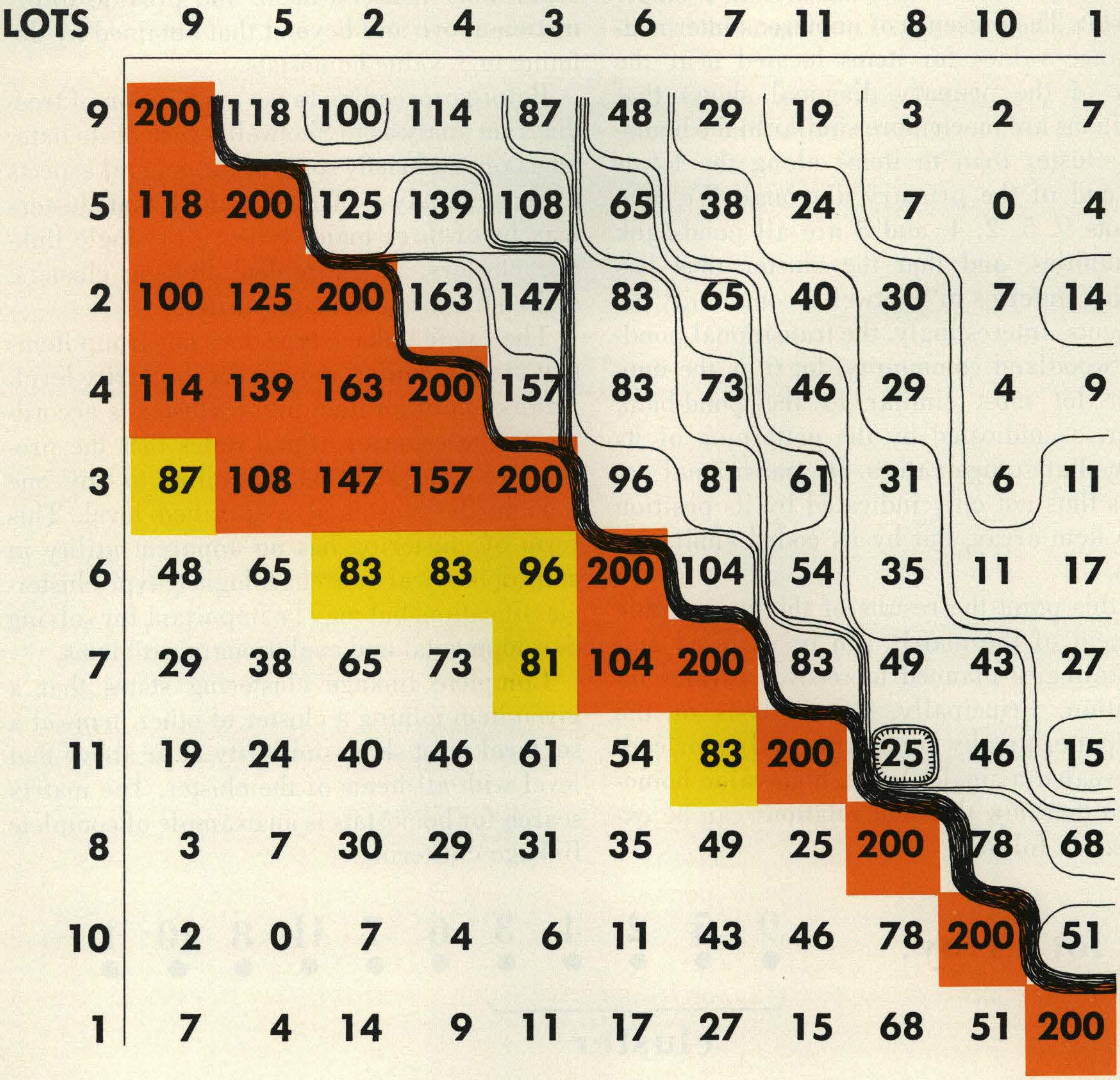
The search for clumps or clusters will consist of a search for *homostats*. A homostat is a group of items which have a degree of similarity to each other above a specified minimum. This is different from a *segregate* which is a group of items whose in-group similarity is markedly greater than the similarity between the grouped items and items outside the group.

Homostats can be discovered by topographic manipulation of the matrix scores once the items are correctly seriated. Brainerd (1951) suggests contouring the similarity matrix by drawing in contour lines at specified intervals. If homostats exist they will show up as plateaus of uniform scores between groups of ideally adjacent and parallel contour lines that indicate abrupt changes in the distribution of score values.

The contoured right half of the matrix in Fig. 5, the seriated vertebrate lots, uses a 10-point contour interval with lines representing Robinson Index values of 10, 20, 30, through 170, the last being the interval just above the highest similarity score of 163. Inspection shows a large plateau of high scores in the upper corner of the matrix adjacent to the primary diagonal of identity scores. In a contoured symmetric matrix, rather than the half-matrix contoured in Fig. 5, the homostat should show up as a square-shaped cluster split diagonally by the identity scores.

Lots 9, 5, 2, 4, and 3 make up this cluster, which is set off topographically by a series of more or less parallel contour lines separating lots 3 and 6. The similarity scores within the cluster are the highest values found in the matrix.

At this point it should be mentioned that the coding of matrix scores by differential shading used by Czekanowski (1911), Kroeber (1940), and others is a somewhat simpler approach to the same kind of topographic relief



LOTS	9	5	2	4	3	6	7	11	8	10	1
9	200	118	100	114	87	48	29	19	3	2	7
5	118	200	125	139	108	65	38	24	7	0	4
2	100	125	200	163	147	83	65	40	30	7	14
4	114	139	163	200	157	83	73	46	29	4	9
3	87	108	147	157	200	96	81	61	31	6	11
6	48	65	83	83	96	200	104	54	35	11	17
7	29	38	65	73	81	104	200	83	49	43	27
11	19	24	40	46	61	54	83	200	25	46	15
8	3	7	30	29	31	35	49	25	200	78	68
10	2	0	7	4	6	11	43	46	78	200	51
1	7	4	14	9	11	17	27	15	68	51	200

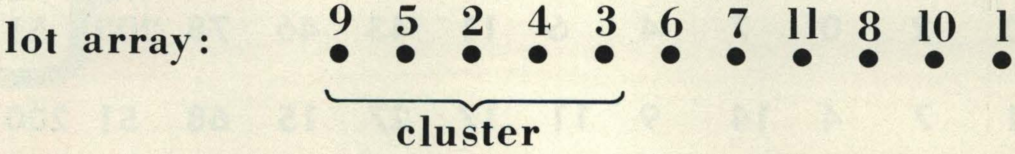
Figure 5. *Seriated and Coded Matrix of Similarity Scores for 11 Late Tertiary Vertebrate Collections. Coefficient H* = 33947, *Matrix Coefficient C* = 1.16252

work. The left half of the matrix in Fig. 5 has been coded this way, only by color instead of shading. After experimenting with different values, three ranges were set: (1) the color orange denotes *high* values equal to, or greater than, 100, the minimum which will be fixed for the homostat; (2) yellow denotes *intermediate* values less than 100 and greater than, or equal to, 80; (3) and no color indicates *low* score values.

In the present instance the inclusion of a single intermediate score (for lots 9 and 3) in the homostat cluster does not seriously injure its homogeneity. Note, however, that if the coded value ranges were re-set to inclue lot 6 in the cluster, the total range of within-cluster scores would be increased enormously and the plateau-like appearance of the cluster would be weakened.

The patterning of similarity scores indicates more, however, than the existence of a single homostat. The presence of numerous intermediate-range values for items located near the center of the primary diagonal shows that these items are much more similar to the homostatic cluster than to items along the lower right end of the primary diagonal. We note that lots 9, 5, 2, 4, and 3 are all pond-bank communities, and that the cluster thus has meaning in terms of Shotwell's community assignments. Interestingly, the transitional pond-bank/woodland community, lot 6, is the non-cluster lot most similar to the pond-bank cluster, as indicated by the patterning of its intermediate-range values. Its transitional nature is thus not only indicated by its position in the item array, but by its coded similarity scores.

At this point the results of the topographic treatment of the matrix can be assessed and new strategies planned to recover further information. Principally, the analysis of the score patterning by contouring and color coding revealed a single, large, high-value homostat, so that now the item relations can be expressed as follows:



The above homostat represents the strongest similarities within the matrix, and has a mean score of 126 for Robinson's Index of Agreement. It is clear, however, that there are other lot relations in the matrix that ought to be considered, but which cannot be discerned by such an elementary form of cluster analysis.

DENDROGRAMS

A method of analysis which is independent of item seriation, but which can be used to good advantage with it, is the construction of tree diagrams from similarity scores. Dendrograms, as the tree diagrams are called, show the degree of similarity for all items by branch connections between them, and provide information above and beyond that obtained by defining high-value homostats.

Before proceeding to the application of tree-diagram analysis to Shotwell's vertebrate data, let us review briefly some of the general aspects of cluster analysis. We know, first, that clusters may be of three major types: (1) single linkage clusters, (2) complete linkage clusters, and (3) average linkage clusters.

The single linkage type does not group items that are all similar above a set similarity level. Admission of an item into a cluster is according to the criterion which states that the prospective item addition is similar to any one item in the cluster at a specified level. This form of clustering has no apparent utility in anthropological or archaeologic *Q*-type cluster-classification, but may be important for solving developmental and evolutionary problems.

Complete linkage clustering states that a given item joining a cluster of other items at a set level must show similarity at or above that level with all items of the cluster. The matrix search for homostats is an example of complete linkage clustering.

Average linkage clustering, proposed by Sokal and Michener (1958), specifies the admission of any item into a cluster on the basis of the average of the similarity scores of that item with the cluster items. As the size of the cluster grows through successive linking, this average similarity necessarily becomes lowered since more remotely similar items are grouped together. The dendrogrammatic technique is of this third type.

Dendrogram analysis was developed in biological taxonomy (Sokal and Sneath 1963). In it, items in either an *R*- or *Q*-technique study are linked progressively by the criterion that the average similarity between members of the

LOTS	1	2	3	4	5	6	7	8	9	10	11
1		14	11	9	4	17	27	68	7	51	15
2	14		147	163	125	83	65	30	100	7	40
3	11	147		157	108	96	81	31	87	6	61
4	9	163	157		139	83	73	29	114	4	46
5	4	125	108	139		65	38	7	118	0	24
6	17	83	96	83	65		104	35	48	11	54
7	27	65	81	73	38	104		49	29	43	*83*
8	68	30	31	29	7	35	49		3	78	25
9	7	100	87	114	118	48	29	3		2	19
10	51	7	6	4	0	11	43	78	2		46
11	15	40	61	46	24	54	83	25	19	46	

basic pairs:
2^1 (2 and 4), 6^1 (6 and 7), 8^1 (8 and 10)

Figure 6. *First Matrix of Similarity Scores with Three Basic Pairs, Late Tertiary Vertebrate Collections*

same group is greater than the average similarity between members of different groups. Items are progressively joined, first into pairs, then into larger groups by an iterative process known as the pair-group method discussed at length by Sokal and Sneath (1963: 181-193, 198-203, 305-317). The recent study on hominid classification by the zoologist A. J. Boyce (1964) is an excellent anthropological example of the use of tree diagrams for clustering purposes.

I have decided, then, to continue this study with the pair group, average linkage, method. Further, the decision has been made to use the *unweighted group method*, one of several possible average linkage procedures (Sokal and Sneath 1963: 191-194). The procedural steps of the method were carried out with a desk calculator. There is readily available, however, an efficient computer program (G. F. Bonham-Carter 1967) for the pair-group method.

The unweighted group method works as follows. An unseriated double matrix of similarity scores for all pairs of items is calculated. Robinson Indexes of Agreement are suitable similarity scores, as are other equal-unit, nor-

$$\begin{array}{c|cccccccc}
 & 2^1 & 6^1 & 8^1 & 1 & 3 & 5 & 9 & 11 \\
\hline
2^1 & & \underline{95} & 52 & 62 & \underline{156} & \underline{142} & \underline{126} & \underline{83} \\
6^1 & 95 & & 53 & 49 & 94 & 69 & 60 & 80 \\
8^1 & 52 & 53 & & \underline{66} & 38 & 28 & 28 & 50 \\
1 & 62 & 49 & \underline{66} & & 11 & 4 & 7 & 15 \\
3 & \underline{156} & 94 & 38 & 11 & & 108 & 87 & 61 \\
5 & 142 & 69 & 28 & 4 & 108 & & 118 & 24 \\
9 & 126 & 60 & 28 & 7 & 87 & 118 & & 19 \\
11 & 83 & 80 & 50 & 15 & 61 & 24 & 19 &
\end{array}$$

basic pairs:

2^2 (2^1 and 3), 8^2 (8^1 and 1)

(A)

$$\begin{array}{c|cccccc}
 & 2^2 & 8^2 & 6^1 & 5 & 9 & 11 \\
\hline
2^2 & & \underline{54} & \underline{105} & \underline{140} & \underline{128} & \underline{102} \\
8^2 & 54 & & 48 & 35 & 35 & 47 \\
6^1 & 105 & 48 & & 69 & 90 & 80 \\
5 & \underline{140} & 35 & 69 & & 118 & 24 \\
9 & 128 & 35 & 90 & 118 & & 19 \\
11 & 102 & 47 & 80 & 24 & 19 &
\end{array}$$

basic pair: 2^3 (2^2 and 5)

(B)

Figure 7. A *Second Matrix with Two Basic Pairs,* **B** *Third Matrix with One Basic Pair*

matized scores. Correlation coefficients cannot be used unless they are transformed into percentages, Fisher's *z*, or to arc cosines of the correlation coefficients.

For illustrative purposes Shotwell's vertebrate collections will now be carried through the various steps of the analysis. First, a double matrix of similarity scores is put together (Fig. 6) exactly as is done before item seriation. The positions which items occupy along the margins of the table are immaterial. Any item permutation may be used. The first computation cycle is a search for *basic pairs,* pairs of items whose members are more similar to each other than to any other items. This can be done by locating the highest score in each column in the double matrix, which is then underlined or circled. Then, column by column, each "highest" score is examined to see if it represents a basic pair, *i.e.,* if it is *the* highest score for the two items which it represents.

The highest score of column 1 is 68, for lots 8 and 1 (Fig. 6). The score does not represent a basic pair, however, because one of its items, lot 8, has a higher similarity score (of 78) with another item (lot 10). The highest score of column 2 is 163 for lots 4 and 2. We find that 163 is the highest similarity score for lot 4 and for lot 2. Therefore these two lots form a basic pair that can be labeled 2^1. When all columns have been inspected this way, three basic pairs are found: 2^1 (lots 2 and 4), 6^1 (lots 6 and 7), and 8^1 (lots 8 and 10).

The second computation cycle involves constructing a new matrix of similarity scores based on the averages of the basic pairs with each other and with single items that do not belong to the basic pairs. The items along the margin of the new matrix (Fig. 7, A) are clusters 2^1, 6^1, 8^1 and lots 1, 3, 5, 9, and 11. The similarity ($\overline{S}$) between lot *i* and a basic pair composed of lots *j* and *k* is calculated as the following mean:

$$\overline{S} = 1/n\ (S_{ij} + S_{ik} + S_{jk}),$$

where *S* is the similarity score (Robinson Index of Agreement) and *n* is the number of original item pair scores being summed. In a like fashion, the similarity between two basic pairs, S_{ij} and S_{kl}, is

$$\overline{S} = 1/6 \quad (S_{ij} + S_{ik} + S_{il} + S_{jk} + S_{jl} + S_{kl}).$$

The above computational formulae are not identical to the procedures for calculating averages used by Sokal and Sneath (1963: 310). To compute the similarity between the basic pairs S_{ij} and S_{kl}, they would perform the operation

$$\overline{S}_{(ij)(kl)} = 1/4\ (S_{ik} + S_{il} + S_{jk} + S_{jl}).$$

It can be seen that similarity scores for the orig-

	2^3	8^2	6^1	9	11
2^3		$\underline{57}$	$\underline{102}$	$\underline{126}$	$\underline{101}$
8^2	57		48	35	47
6^1	102	48		90	80
9	$\underline{126}$	35	90		19
11	101	47	80	19	

basic pair: 2^4 (2^3 and 9)

(A)

	2^4	8^2	6^1	11
2^4		$\underline{58}$	$\underline{96.3}$	$\underline{96}$
8^2	58		48	47
6^1	$\underline{96.3}$	48		80
11	96	47	80	

basic pair: 2^5 (2^4 and 6^1)

(B)

Figure 8. A *Fourth Matrix with One Basic Pair,* **B** *Fifth Matrix with One Basic Pair*

	2^5	8^2	11
2^5		$\underline{57}$	$\underline{84}$
8^2	57		47
11	$\underline{84}$	47	

basic pair: 2^6 (2^5 and 11)

(A)

	2^6	8^2
2^6		54
8^2	54	

basic pair: 2^7 (2^6 and 8^2)

(B)

Figure 9. A *Sixth Matrix with One Basic Pair,*
B *Seventh Matrix with One Basic Pair*

inal basic pairs S_{ij} and S_{kl} are omitted. I include them because my interest is in the average value for all possible original item scores of all possible item combinations for the potential grouping.

A search of the second matrix (Fig. 7, A) for new basic pairs produces 2^2 (2^1 and 3) and 8^2 (8^1 and 1). The procedure of calculating new, ever smaller matrices and seeking new pairs is continued (Figs. 7, B; 8, 9) until finally a minimal two-by-two matrix remains (Fig. 9, B).

At this point all items have been joined at some level, and the dendrogram can be drawn to show the points at which joining has taken place (Fig. 10). The vertical scale of Fig. 10 gives the average similarity of all the lots joined at any one point on the scale. For instance, lots 2 and 4, the first basic pair, are joined at 163, the value that represents their similarity score; lot 3 is joined to lots 2 and 4 at 156, which is the average ($\overline{S}$) of the three scores S_{23} (147), S_{24} (163), and S_{34} (157).

The horizontal axis of the standard dendrogram is not interpretable. The distances between lots may or may not be equal, as the illustrator wishes. Also, the position of cluster items along this axis is irrelevant.

Something else should be done before the tree diagram is in its final form. It is recommended that the results of item seriation and tree-diagram study be combined in a single chart whenever possible. To do this, the items along the horizontal axis of the dendrogram are arranged in their final array produced by item seriation (Fig. 11). This has the effect, in one sense, of doubling the amount of information about item relations given by item seriation or dendrogrammatic analysis alone. This graphing procedure seems to be a distinct methodological refinement. However, it is sometimes impossible to arrange items in a dendrogram according to their seriation, especially in large data sets. The results of the two techniques need not be sufficiently close to allow this.

Fig. 11, the final chart of item relations, tells us this:

1. There is a homogeneous cluster of similar items represented by lots 2, 3, 4, 5, and 9. This agrees with the cluster derived from the search for homostats.

2. At a lower level of similarity the transitional pond-bank/woodland, woodland, and border communities join the above cluster. This information is somewhat comparable to that provided by the final item seriation of the lots, although seriation shows the obviously transitional nature of lot 6 better than the dendrogram does.

3. The savanna and grassland communities exhibit a rather low degree of similarity among themselves, but the similarity among these lots is stronger than it is between any one of them and other lots in the data set.

The present results, in terms of clustering, agree with Shotwell's (1955, 1958, 1963) community typing, but not necessarily for the same reasons. Shotwell identified inter-collection similarity by comparing only the animal forms of the proximal communities recognized

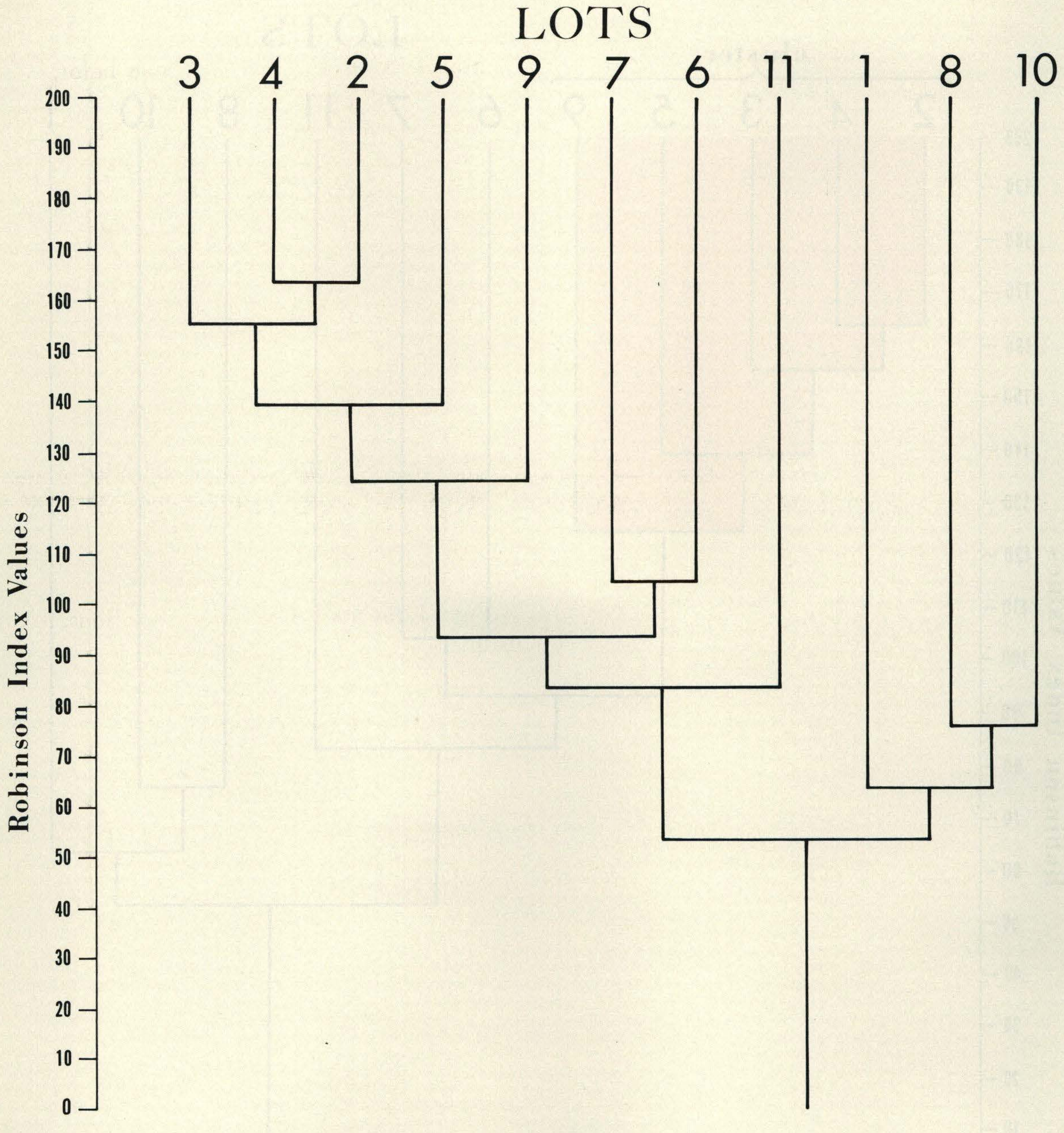


Figure 10. *Dendrogram for Late Tertiary Vertebrate Collections*

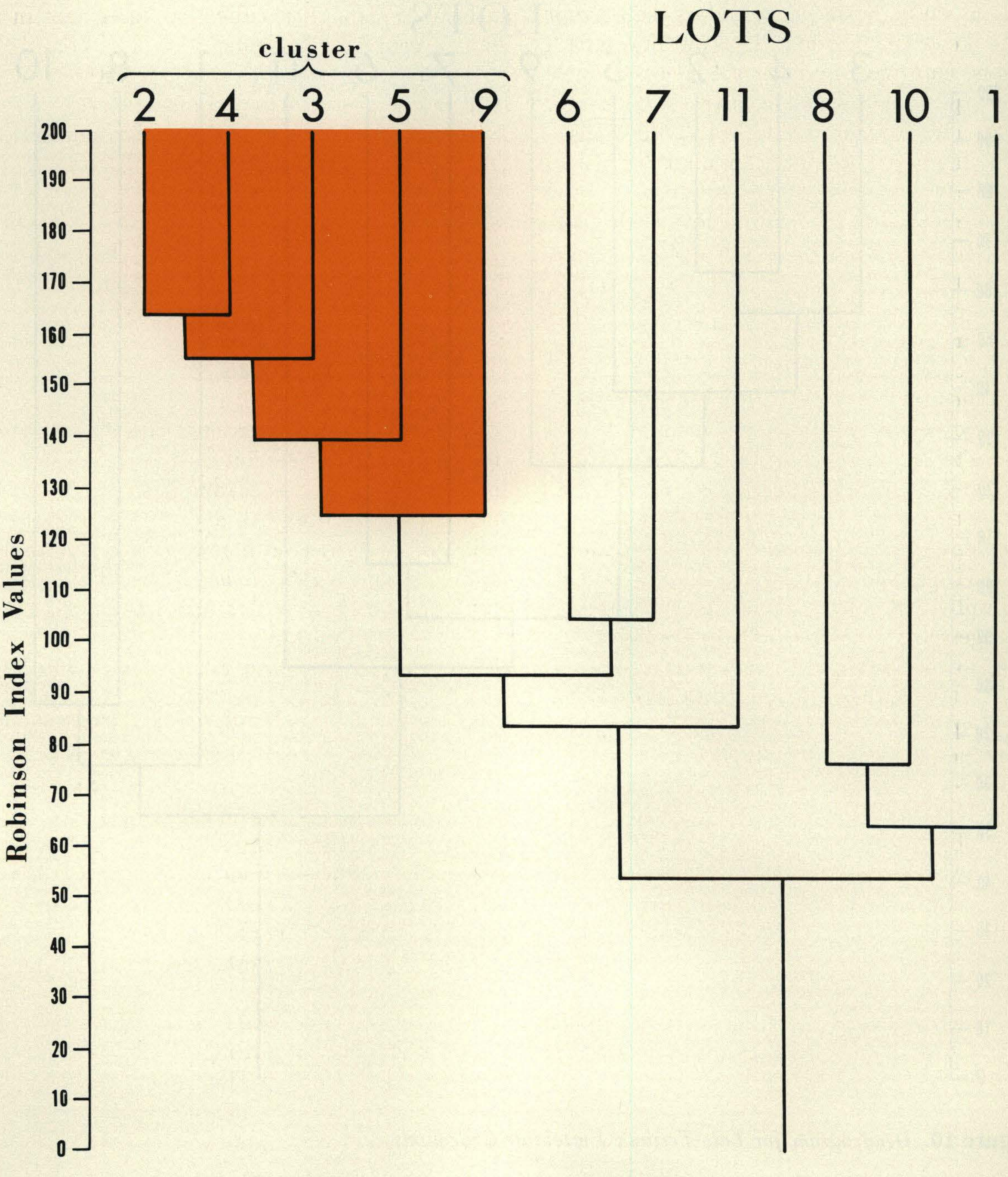


Figure 11. *Dendrogram with Lots Placed in Seriated Array*

by their high element per individual ratio. The present study, however, considers the percentages of every form and utilizes the total sample counts. Our basic agreement suggests that the use of percentages, alone, may be just as accurate a way to cluster vertebrate collections as the isolation of proximal community members and their comparison. If this is true, it is so because forms with a high element per individual ratio tend to be dominant in their respective faunal collections. Stating the reverse of this, forms which have a low element per individual ratio tend also to be rare. Happily, the Robinson Index of Agreement is able to minimize the effects of rare, often intruded, forms on a collection whether this mixture results from stratigraphic migration or contemporary intrusions from one or more distal communities.

The present study has perhaps made an additional contribution in that it suggests that Shotwell's community types are not equally homogeneous constructs. There is clearly less variation in the pond-bank community type than in the others, and this is reasonable since other types, such as savanna, would be expected to include more varied kinds of habitats than a pond-bank. Unfortunately there are other sources of variation in the data set that make this, at best, only a reasonable hypothesis to be tested with additional data. For instance, several of the pond-bank collections are samples of the same faunal bed. There is less phylogenetic continuity between lots 1, 8, and 10 than in the forms of cluster lots 2, 3, 4, 5, and 9. Also, lot 1 is separated from lots 8 and 10 by a much greater distance than any of the collections in the pond-bank cluster.

R-TECHNIQUE OGIVES

Once the *Q*-technique comparison of collections is completed and clusters of similar lots have been recognized, the next analytic step is to determine which forms are responsible for the clustering tendencies. An *R*-technique comparison between forms will provide the answer. A simple but effective way to do this graphically is to use ogives, cumulative percentage diagrams, to show inter-collection agreement in item percentages. Percentages must be considered since the *Q*-technique study with Robinson Indexes of Agreement is percentage based.

Fig. 12 diagrams the cumulative percentages of the 48 genera and species of the homostat represented by lots 2, 3, 4, 5, and 9, and shows for contrast the distribution of forms for lot 10, which is outside this cluster. Genera and species that have a marked vertical percentage increase for several lots simultaneously are the forms contributing heavily to the high similarity scores of those lots. Inspection of Fig. 12 discloses that forms 5, 15, and 35 all have high percentages in the cluster lots, while forms 10 and 23 have moderate, but consistent, percentages for the same lots. From Table 3 we see that forms 5, 15, 35, 10, and 23 are, respectively, *Hypolagus* (rabbit), *Dipoides* and *Eucastor* (beavers), *Prosthennops* (peccary), *Citellus* (ground squirrel), and *Canis* (small dog).

The above forms are among those which Shotwell has used to characterize the pond-bank community type (Shotwell 1958: 282, Fig. 13; 1963: 16, 18), but represent only a part of the list of characteristic proximal forms. However, we have determined here that they dominate their respective collections and are most representative of pond-bank communities because of this dominance. This is an important datum and can be added to the extant information about pond-bank vertebrate communities of the late Tertiary.

Ogives can also be used to simplify the rank-ordering of items according to their relative effect on lot clustering. This effect can be determined roughly, and items ranked accordingly, in one of two simple ways. The first involves calculating common influence, the agreement among the percentages for form *A*, say, in lots 1, 2, and 3. If *A* is 35 per cent of lot 1, 20 per cent of lot 2, and 30 per cent of lot 3, its common influence on this lot cluster is 20, the inter-lot agreement for *A*. Calculating average influence is the second way. The average

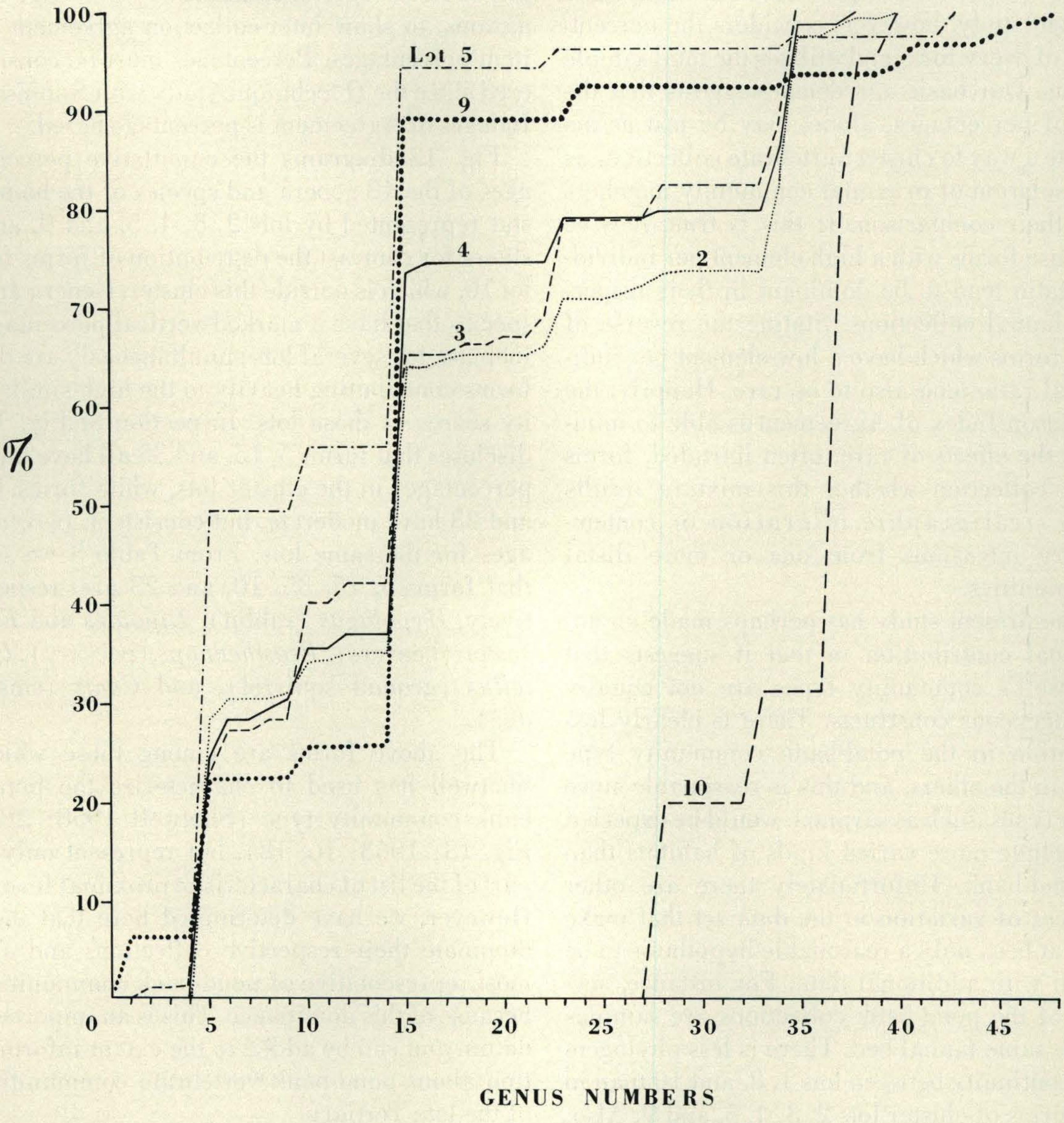


Figure 12. *Ogives for Lots* 2, 3, 4, 5, 9, *and* 10

influence of A is $(35 + 20 + 30)/3 = 28$ in the above hypothetical example.

The average influence of the dominant vertebrates of the homostatic cluster can easily be calculated from the ogives of Fig. 12. The resulting rank-order, with most dominant form first, is 15, 5, 35, 10, and 22: beavers, rabbit, peccary, ground squirrel, and small dog, respectively.

Only the one cluster, the homostat, has been examined here to find out which forms are dominant and by inference responsible for clustering. However, new ogival graphs could be computed for any combination of lots from the dendrogrammatic groupings, and the process could be repeated to single out and rank-order dominant forms.

THE FRENCH PALEOLITHIC

The 26 Paleolithic artifact collections are assigned lot numbers in Table 4, and each lot is identified by name, stratigraphic provenience, cultural assignment, sample size, and publication source. All the sites are located in the famous valleys of southwestern France: along the Dronne, Vézère, Cern, and Dordogne rivers. Only lithic specimens will be considered in the comparison that follows.

The artifact collections are Upper Paleolithic in style and age, and represent three of the four great Upper Paleolithic cultural traditions—the Perigordian (7 lots), the Aurignacian (7 lots), and the Solutrean (12 lots). Magdalenian assemblages are omitted to keep the data set within manageable size limits.

The 26 collections have been summarized and compared by D. de Sonneville-Bordes (1960), whence the present data come. The 12 Solutrean collections are also presented in P. E. Smith's (1966) excellent synthesis of that cultural tradition. In their comparative studies, de Sonneville-Bordes and Smith use several simple and efficient techniques that are usually considered the hallmark of François Bordes. For the most part they employ cumulative percentage graphs (ogives) for the 92 Upper Paleolithic artifact types (defined in de Sonneville-Bordes 1960: Vol. I, pp. 27, 28), and indexes based on artifact class proportions in the total lithic samples. The indexes, *e.g.*, *IG* (Scraper Index) and *IB* (Burin Index), are explained in detail elsewhere (*ibid.*: 28, 29).

It was necessary to set some arbitrary limit on sample size in selecting from among the many Upper Paleolithic periodized site collections. Some consist of only a few dozen specimens and are unsuitable for quantitative comparison since there are many artifact types—92—in the French Upper Paleolithic. The figure 400 was chosen as a minimum collection size.

It would be ideal in this kind of study to select a large number of collections for each culture type, and then do similarity scaling and cluster studies to find out which resemble each other enough so that they can be classed together. Each culture type would be well represented in the sample. This procedure is impossible to follow because several of the culture types are rare and poorly represented archaeologically. Also, more than one important collection had to be excluded because of its small size.

The 26 lots are currently classed by many prehistorians into the culture types given in Fig. 13, partly on the basis of diagnostic artifacts called *fossiles directeurs*. The sequence from bottom to top of the figure reflects the known stratigraphic superposition of the culture types at the three key sites of La Ferrassie, Laugerie-Haute, and Pataud. Note that the chosen lots fail to represent the Evolved Aurignacian and the Proto-Magdalenian entirely, while other culture types such as the Lower Perigordian and "Final" Aurignacian are represented by only one collection each. In contrast, eight of the 26 lots are Upper Solutrean.

The lack of uniformity in the distribution of lots by culture types is unfortunate in some ways but useful in others. As a test case for seriation and cluster-classification techniques it is good to have a large number of lots from a single culture type such as the Upper Solutrean. If these lots are classed either separately or together in the following study, something will perhaps have been learned about the "nature" of the Upper Solutrean. And even with an uneven distribution of lots, there is still the possibility that lots belonging to different culture types may be classed together.

The site of Badegoule provides an interesting test case. Two collections (Peyrony, Peyrille) from the same stratigraphic unit are included as lots 19 and 20. In effect, one collection is divided in two. As a simple test, seriation should be able to show the postulated extreme similarity of the two lots. If it cannot, then the two artifact collections were classified differently, there is extreme sampling error between them, or else we had best look for a new comparative technique!

latest—Upper Solutrean [lots 19, 20, 21, 22, 23, 24, 25, 26]
↑
Middle Solutrean [lot 18]
Lower Solutrean [lots 16, 17]
Proto-Solutrean [lot 15]
Proto-Magdalenian
Aurignacian V [lot 14]
Perigordian "III" [lot 2]
Perigordian V [lot 7]
Perigordian IV [lot 3]
} undifferentiated Upper Perigordian [lots 4, 5, 6,]
"Final" Aurignacian (IV) [lot 13]
Evolved Aurignacian (III)
Middle Aurignacian (II) [lots 11, 12]
Aurignacian I [lots 8, 9, 10]
earliest—Lower Perigordian (I) [lot 1]

Figure 13. *Sequence of Upper Paleolithic Culture Types with Lot Assignments*

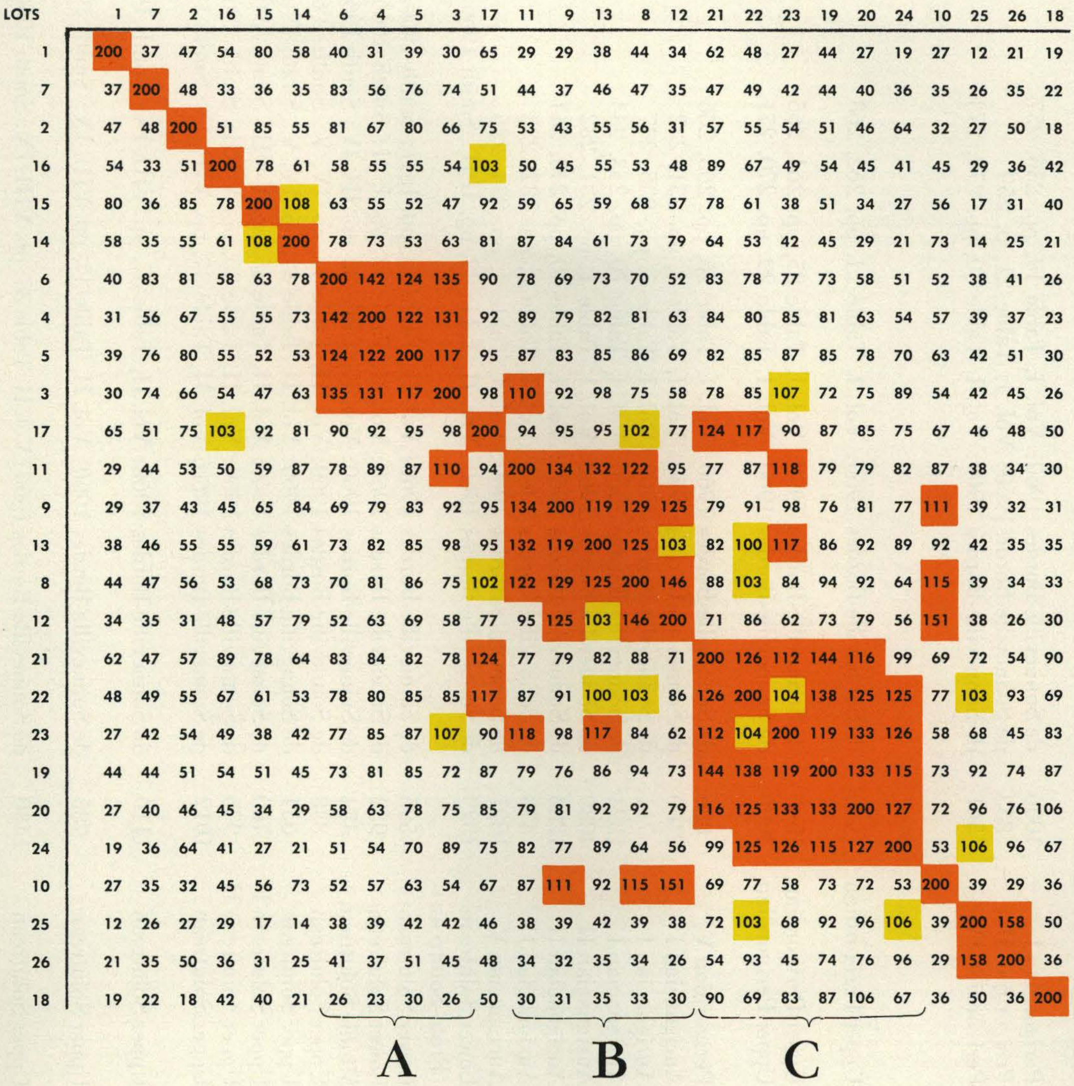
ITEM SERIATION

As in the case of the late Tertiary vertebrate collections, the first part of the study is simple scale analysis by item seriation with PROGRAM SERIATE. Percentages and Robinson Indexes of Agreement were calculated. Then these similarity scores were placed in a data matrix and seriated with the same data processing equipment used on the first data set.

Since the number of lots is over twice as large as it was for the vertebrate collections, it is likely that lot relations may also be more complex and that a good seriation may be more difficult to find. With this in mind, 20 seriation tries were made with the computer, each with a different lot permutation input to help eliminate input bias. The best seriation produced a Coefficient *H* of 758660 and a Matrix Coefficient *C* of 1.24139. The corresponding item array of lots appears in Fig. 14, providing an overview of relations according to *C*-type similarity scaling (Fig. 1).

To begin with, the appropriate culture types can be listed by each lot in the seriated array of Fig. 14 as follows:

lot no.	*culture type*
1	Lower Perigordian
7	Perigordian V
2	Perigordian "III"
16	Lower Solutrean
15	Proto-Solutrean
14	Aurignacian V
6	Upper Perigordian
4	UpperPerigordian
5	Upper Perigordian
3	Perigordian IV
17	Lower Solutrean
11	Middle Aurignacian
9	Aurignacian I
13	"Final" Aurignacian
8	Aurignacian I
12	Middle Aurignacian
21	Upper Solutrean
22	Upper Solutrean
23	Upper Solutrean
19	Upper Solutrean
20	Upper Solutrean
24	Upper Solutrean
10	Aurignacian I
25	Upper Solutrean
26	Upper Solutrean
18	Middle Solutrean



LOTS	1	7	2	16	15	14	6	4	5	3	17	11	9	13	8	12	21	22	23	19	20	24	10	25	26	18
1	200	37	47	54	80	58	40	31	39	30	65	29	29	38	44	34	62	48	27	44	27	19	27	12	21	19
7	37	200	48	33	36	35	83	56	76	74	51	44	37	46	47	35	47	49	42	44	40	36	35	26	35	22
2	47	48	200	51	85	55	81	67	80	66	75	53	43	55	56	31	57	55	54	51	46	64	32	27	50	18
16	54	33	51	200	78	61	58	55	55	54	103	50	45	55	53	48	89	67	49	54	45	41	45	29	36	42
15	80	36	85	78	200	108	63	55	52	47	92	59	65	59	68	57	78	61	38	51	34	27	56	17	31	40
14	58	35	55	61	108	200	78	73	53	63	81	87	84	61	73	79	64	53	42	45	29	21	73	14	25	21
6	40	83	81	58	63	78	200	142	124	135	90	78	69	73	70	52	83	78	77	73	58	51	52	38	41	26
4	31	56	67	55	55	73	142	200	122	131	92	89	79	82	81	63	84	80	85	81	63	54	57	39	37	23
5	39	76	80	55	52	53	124	122	200	117	95	87	83	85	86	69	82	85	87	85	78	70	63	42	51	30
3	30	74	66	54	47	63	135	131	117	200	98	110	92	98	75	58	78	85	107	72	75	89	54	42	45	26
17	65	51	75	103	92	81	90	92	95	98	200	94	95	95	102	77	124	117	90	87	85	75	67	46	48	50
11	29	44	53	50	59	87	78	89	87	110	94	200	134	132	122	95	77	87	118	79	79	82	87	38	34	30
9	29	37	43	45	65	84	69	79	83	92	95	134	200	119	129	125	79	91	98	76	81	77	111	39	32	31
13	38	46	55	55	59	61	73	82	85	98	95	132	119	200	125	103	82	100	117	86	92	89	92	42	35	35
8	44	47	56	53	68	73	70	81	86	75	102	122	129	125	200	146	88	103	84	94	92	64	115	39	34	33
12	34	35	31	48	57	79	52	63	69	58	77	95	125	103	146	200	71	86	62	73	79	56	151	38	26	30
21	62	47	57	89	78	64	83	84	82	78	124	77	79	82	88	71	200	126	112	144	116	99	69	72	54	90
22	48	49	55	67	61	53	78	80	85	85	117	87	91	100	103	86	126	200	104	138	125	125	77	103	93	69
23	27	42	54	49	38	42	77	85	87	107	90	118	98	117	84	62	112	104	200	119	133	126	58	68	45	83
19	44	44	51	54	51	45	73	81	85	72	87	79	76	86	94	73	144	138	119	200	133	115	73	92	74	87
20	27	40	46	45	34	29	58	63	78	75	85	79	81	92	92	79	116	125	133	133	200	127	72	96	76	106
24	19	36	64	41	27	21	51	54	70	89	75	82	77	89	64	56	99	125	126	115	127	200	53	106	96	67
10	27	35	32	45	56	73	52	57	63	54	67	87	111	92	115	151	69	77	58	73	72	53	200	39	29	36
25	12	26	27	29	17	14	38	39	42	42	46	38	39	42	39	38	72	103	68	92	96	106	39	200	158	50
26	21	35	50	36	31	25	41	37	51	45	48	34	32	35	34	26	54	93	45	74	76	96	29	158	200	36
18	19	22	18	42	40	21	26	23	30	26	50	30	31	35	33	30	90	69	83	87	106	67	36	50	36	200

Figure 14. *Seriated and Coded Matrix of Similarity Scores for 26 Upper Paleolithic Artifact Collections. Coefficient* $H = 758660$, *Matrix Coefficient* $C = 1.24139$. *Homostats A, B, and C*

TABLE 4, Key to Lot Identification, Upper Paleolithic Artifact Collections

LOT	SITE	DEPOSIT	CULTURAL ASSIGNMENT	N	SOURCE
1	La Ferrassie	Stratum E	Perigordian I	1000	de Sonneville-Bordes 1960; Vol. I, Table 19, pp. 256, 257
2	Laugerie-Haute, East	Stratum B	Perigordian III$_1$	858	de Sonneville-Bordes1960: Vol. I, Table 21, p. 259
3	Fourneau-du-Diable	Lower stratum, lower terrace	Perigordian IV	561	de Sonneville-Bordes 1960: Vol. I, Table 30, pp. 272, 273
4	La Roque Saint-Christophe		Upper Perigordian	969	de Sonneville-Bordes 1960: Vol .I, Table 24, pp. 262, 263
5	Font Robert		Upper Perigordian	1500	de Sonneville-Bordes 1960: Vol. I, Table 25, pp. 264, 265
6	Labattut	(combined strata)	Upper Perigordian	3096	de Sonneville-Bordes 1960: Vol. I, Table 29, pp. 270, 271
7	La Ferrassie	Stratum J	Perigordian V$_1$	886	de Sonneville-Bordes 1960: Vol. I, Table 26, pp. 265, 266
8	La Ferrassie	Stratum F	Aurignacian I	2460	de Sonneville-Bordes 1960: Vol. I, Table 1, pp. 231, 232
9	Lartet		Aurignacian I	711	de Sonneville-Bordes 1960: Vol. I, Table 5, pp. 236, 237
10	Castanet		Aurignacian I	1824	de Sonneville-Bordes 1960: Vol. I, Table 10, pp. 243, 244
11	La Ferrassie	Stratum H	Aurignacian II	4039	de Sonneville-Bordes 1960: Vol. I, Table 1, pp. 231, 232
12	Castanet		Aurignacian II	1283	de Sonneville-Bordes 1960: Vol. I, Table 10, pp. 243, 244
13	La Ferrassie	Stratum H"	Aurignacian IV	473	de Sonneville-Bordes 1960: Vol. I, Table 2, pp. 232, 233
14	Laugerie-Haute, West	Stratum D	Aurignacian V	1621	de Sonneville-Bordes 1960: Vol. I, Table 3, pp. 234, 235
15	Laugerie-Haute, West	Stratum G	Lower Solutrean (Proto-Solutrean)	1329	de Sonneville-Bordes 1960: Vol. II, Table 32, pp. I, II; Smith 1966: p. 399
16	Laugerie-Haute, West	Stratum H'	Lower Solutrean	595	de Sonneville-Bordes 1960: Vol. II, Table 32, pp. I, II; Smith 1966: pp. 408, 409
17	Laugerie-Haute, East	Stratum H'	Lower Solutrean	933	de Sonneville-Bordes 1960: Vol. II, Table 32, pp. I, II; Smith 1966: pp. 409, 410
18	Laugerie-Haute, West	Stratum H"	Middle Solutrean	454	de Sonneville-Bordes 1960: Vol. II, Table 33 pp. III, IV; Smith 1966: pp. 408, 409
19	Badegoule (Peyrony)		Upper Solutrean	838	de Sonneville-Bordes 1960: Vol. II, Table 34, pp. IV, V; Smith 1966: pp. 410, 411
20	Badegoule (Peyrille)		Upper Solutrean	654	de Sonneville-Bordes 1960: Vol. II, Table 34, pp. IV, V; Smith 1966: pp. 410, 411
21	Pech de la Boissière		Upper Solutrean I	760	de Sonneville-Bordes 1960: Vol. II, Table 35, pp. V-VII; Smith 1966: pp. 412, 413
22	Pech de la Boissière		Upper Solutrean II	976	de Sonneville-Bordes 1960: Vol. II, Table 35, pp. V-VII; Smith 1966: pp. 412, 413
23	Le Fourneau-du-Diable	Lower terrace	Upper Solutrean	1012	de Sonneville-Bordes 1960: Vol. II, Table 37, pp. VIII, IX; Smith 1966: pp. 416, 417
24	Le Fourneau-du-Diable	Upper terrace I	Upper Solutrean	1110	de Sonneville-Bordes 1960: Vol. II, Table 37, pp. VIII, IX; Smith 1966: pp. 416, 417
25	Le Fourneau-du-Diable	Upper terrace II	Upper Solutrean	785	de Sonneville-Bordes 1960: Vol. II, Table 37, pp. VIII, IX; Smith 1966: pp. 416, 417
26	Le Fourneau-du-Diable	Upper terrace III	Upper Solutrean	1430	de Sonneville-Bordes 1960: Vol. II, Table 37, pp. VIII, IX; Smith 1966: pp. 416, 417

This seriation will, I think, initially appear meaningless to the archaeological reader. For one thing, the archaeologists who normally use seriation have a strong predilection for viewing it only as a dating technique, a method which can be applied more or less automatically to obtain the proper relative ages of items in a given data set. This view is of course nonsense, but it is widespread. Many of the problems which can be seen in the new Hole and Shaw publication (1967) on seriation are due to this kind of misunderstanding. They will be mentioned later.

It is good to emphasize at this point, therefore, that seriation is a descriptive technique and nothing more. It arranges items (collections) unidimensionally so that the position of each item reflects its degree of similarity to all other items, similarity thus being expressed as positional proximity. Whenever one begins discussing relative dating, at that point he is doing interpretation as opposed to description. The latter must always precede the former.

Plainly, the lot sequence of Fig. 14 does not agree with the known relative ages of the lots given in Fig. 13 as determined by unequivocal stratigraphic superposition. Thus differences between collection positions in the seriated array cannot be explained by gradual artifact type fluctuations and replacements through time, at least not by the regular type of replacement discussed by Robinson (1951) and Brainerd (1951).[3]

Factors other than time must account for the positions of items in the ordered series. If we assume that the French artifact typology is capable of accurately revealing the kind of temporal fluctuation in the frequency of types that is necessary for relative dating purposes, then we can conclude that no such simple evolutionary sequence of culture forms is represented by that segment of the Upper Paleolithic of southwestern France treated here. Historically different traditions must be present among the 26 lots. This point will be discussed when interpretations of the French archaeological sequence are dealt with later.

CLUSTER SEARCH

The *C*-value of 1.24139 for the best seriated item permutation tells us that there is no gradual progression in the final similarity scale from one end of the series to the other. A *C*-value of approximately 2 would have indicated such patterning. As in the case of the best *C*-value of 1.16252 for the vertebrate collections, the best Matrix Coefficient *C* for the Paleolithic collections very strongly suggests the existence of clumps of comparable similarity scores which need to be sought out.

Homostats were first searched for by contouring the seriated matrix (not illustrated), and by experimenting with color-coding to find clumps of high scores adjacent to the diagonal of identity (Fig. 15). An additional aid was used to set score intervals for the coding process. All the $n(n-1)/2$ similarity scores were plotted in a frequency chart (Fig. 15), the purpose being to show natural breaks in score distribution, should they exist, that could serve to set off *high*, *intermediate*, or some such group intervals. Fig. 15 shows what seems to be an irregular mode of score values above 110. Thus Robinson Indexes of Agreement of this value or greater are coded as *high* scores by using the color orange. Also, an *intermediate* range of 100-109 is set to show score gradation within the matrix, using yellow for this range. The absence of color indicates *low* similarity score values.

Fig. 14 shows three distinct homostatic clusters labeled *A*, *B*, and *C*. Although they are so designated here, clusters *B* and *C* are not per-

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[3] It should perhaps be mentioned that seriation within a single functional tool class, such as scrapers or burins, might produce results more in agreement with chronology than seriation based on total lithic assemblages. If this is true, it is because stylistic replacement of one type by another occurs within the limits of a particular functional category or class. Fluctuations in the popularity of burin type *X* would influence, in such cases, only the percentages of other burin types, not the percentages of non-burin artifact types. J. R. Sackett (1966) tried this approach, using end scrapers and burins, with six French Aurignacian sites and produced a seriation of strata which may correspond to true chronological order. However, no such study has been done between deposits of different major traditions, such as the Perigordian with the Solutrean.

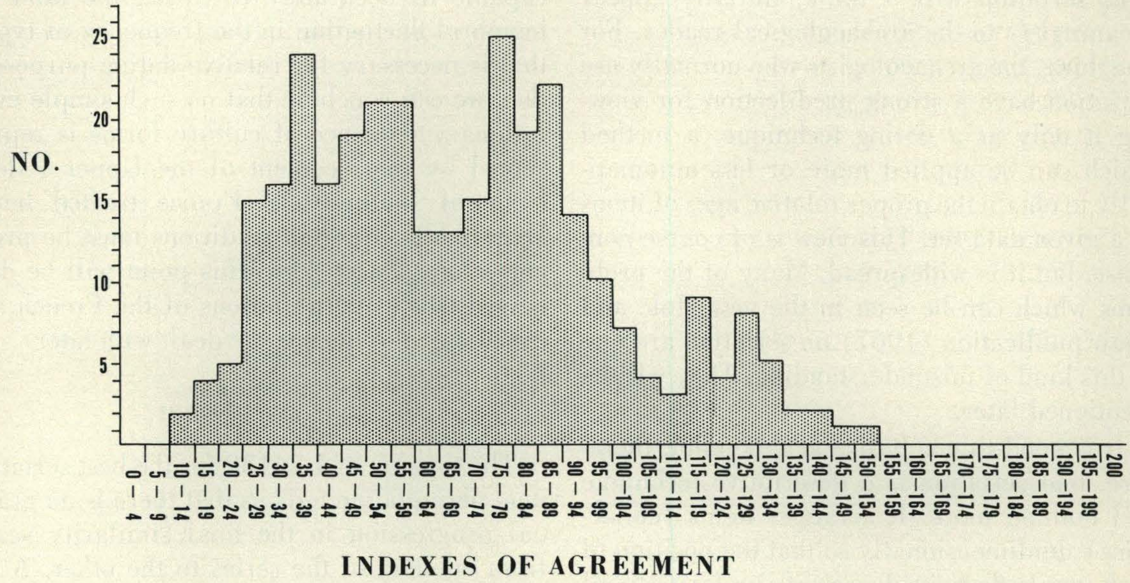

Figure 15. *Frequency Distribution of Similarity Scores for 26 Upper Paleolithic Artifact Collections*

fect homostats; that is to say, not all of their included similarity scores are *high* and fit the set limiting value of 110. But the approximation of these two clusters to homostats is very close, and I see no serious problems in a slight relaxation of definitional criteria when it facilitates pattern recognition.

Cluster *A* (lots 3 through 6) is composed entirely of Upper Perigordian artifact collections from Fourneau-du-Diable, La Roque Saint-Christophe, Font Robert, and Labattut. The uniformity within this group of site collections is strong and is interesting from several standpoints. First, the mean similarity score of the homostat is 128, which is quite high when compared to the score distribution of Fig. 15. Second, cluster *A* stands apart very distinctly from its nearest neighboring lots on the primary diagonal (see Fig. 14). Lot 14, adjacent to the upper left of cluster *A*, is Aurignacian V and is quite dissimilar to the cluster. Lot 17, situated to the lower right of the cluster, is Lower Solutrean and also quite dissimilar to the cluster lots, but not so markedly so as lot 14. Third, there is no strong resemblance between the Upper Perigordian lots of cluster *A* and the most ancient Perigordian site collection, lot 1 (Perigordian I). Fourth, cluster *A* has a brief temporal duration relative to that of the homostat, cluster *B*.

Cluster *B* (lots 8, 9, 11, 12, 13) consists of Aurignacian stratigraphic assemblages from La Ferrassie (three lots), Lartet (one lot), and Castanet (one lot). The mean score for the cluster is 123, only 5 points less than the average of cluster *A*. However, the cluster merges or blends more gradually with its adjacent collections: lot 17 (Lower Solutrean) on the upper left, and lot 21 (Upper Solutrean) on the lower right (Fig. 14). Early Aurignacian (I), Middle Aurignacian (II) and later Aurignacian (IV) site collections are represented, giving the cluster a rather considerable temporal range. In comparison with cluster *A*, cluster *B* indicates that "Aurignacianness" is a more uniform thing (through time) than "Perigordianness," at least insofar as the two qualities can be measured with Robinson Indexes of Agreement and the extant French artifact typology. This is common knowledge, of course, and is embodied in the nomenclature used largely outside France, in which Perigordian I is called Châtelperronian (*Castelperronien*) and the Upper Perigordian is termed Gravettian.

Cluster *C* (lots 19 through 24) consists only of Upper Solutrean collections from the sites of Badegoule, Pech de la Boissière, and Le Fourneau-du-Diable. In it are all the Upper Solutrean artifact collections included in the present sample of 26 lots, except lots 25 and 26. The average score value is 123. Cluster *C* is like cluster *A* in that it is of brief temporal duration, and like *B* in that it tends to blend or intergrade with its surrounding, non-cluster, lots. The Lower and Middle Solutrean collections do not form part of the cluster, and some of them such as lots 15 and 16 (the Lower Solutrean at Laugerie-Haute, West) are located near the opposite end of the seriated array. This means that in terms of dominant lithic artifact types, there are very major differences between the Lower and Upper Solutrean artifact collections that were analyzed.

We should note at this point that the two collections, lots 19 and 20, from the same stratum at Badegoule have been classed similarly. As a test of our seriation and clustering techniques, the two lots pass with flying colors (see p. 27).

DENDROGRAMS

Having finished the complete linkage clustering, we can now try an average linkage analysis of the 26 Paleolithic lots. The unweighted group method of constructing a tree-diagram was applied exactly as with the vertebrate data set. The final dendrogram of item relations appears in Fig. 16.

The reader will remember that after the search for basic pairs had been finished for the vertebrate data, and the basic dendrogram drawn, a new tree diagram was constructed in which the item positions were arranged horizontally across the chart so as to agree with the seriation of the lots (Fig. 11). This cannot be done in the case of the Paleolithic artifact collections. The results of seriation and tree diagram linkage are sufficiently different so that the seriated array cannot be followed in arranging the branches of the dendrogram. Considering that dendrograms are based on average similarities between items, this result is not too surprising in a large and complex data set. Fig. 16 will have to stand as is.

The following information can be gotten from Fig. 16. Depending on where one draws cluster limits, several homogeneous groups of similar items can be discerned. If an average similarity score limit of 110 is set (the minimum value for the *high* score interval used in defining the homostats), four clusters result: I (lots 3 through 6), II (lots 8 through 13), III (lots 25 and 26), and IV (lots 18 through 24). They are average linkage clusters, not homostats. Nevertheless, the content of clusters I, II, and IV is very close to that of homostats *A*, *B*, and *C*, respectively.

Clusters I and *A* are identical. They contain the Upper Perigordian collections from Fourneau-du-Diable, La Roque Saint-Christophe, Font Robert, and Labattut. Cluster II is like cluster *B*, except that it adds lot 10, the Aurignacian I assemblage from Castanet. This addition does not change the interpretation of cluster *B*, which contains Aurignacian I, II, and IV collections from La Ferrassie, Lartet, and Castanet. Lot 10, however, strengthens the argument for considerable cluster duration, since it provides an additional early Aurignacian example.

Cluster III is a two-lot (25, 26) grouping of the Upper Solutrean (Upper Terrace II and III) from Le Fourneau-du-Diable. Because the purpose of matrix cluster-classification is to go beyond paired lot similarities, no two-lot groups were defined in the search for homostats. Such a matrix unit would be impossible since it would be represented by a single similarity score, as opposed to a clump of scores. The importance of defining cluster III here is that it shows that clusters of Upper Solutrean collections may be present in the area which are distinct from the Upper Solutrean of cluster *C*. In actuality, however, lots 25 and 26 illustrate only the similarity of two cultural deposits at the same site. The cluster will not be considered further.

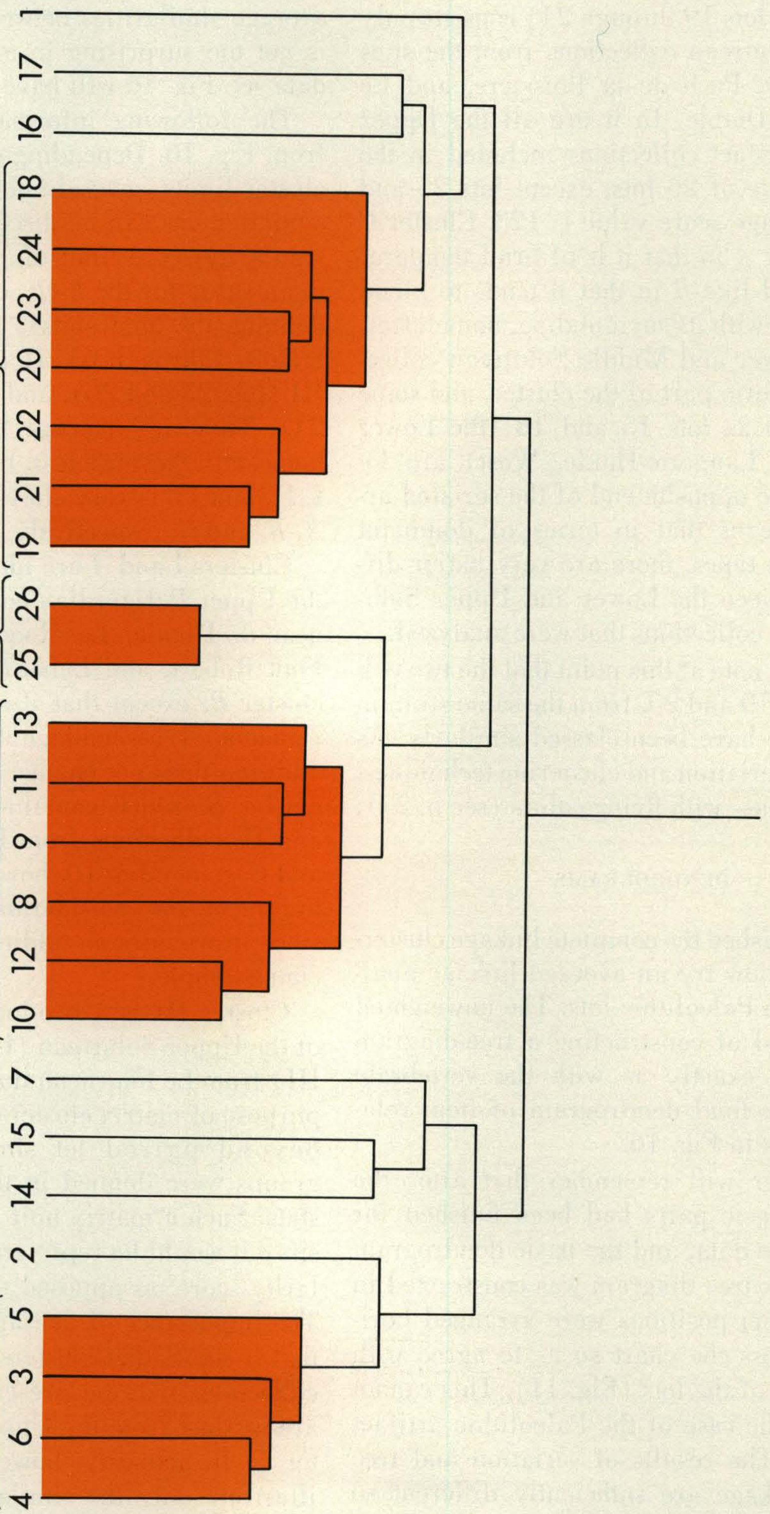

Figure 16. *Dendrogram of 26 Upper Paleolithic Artifact Collections*

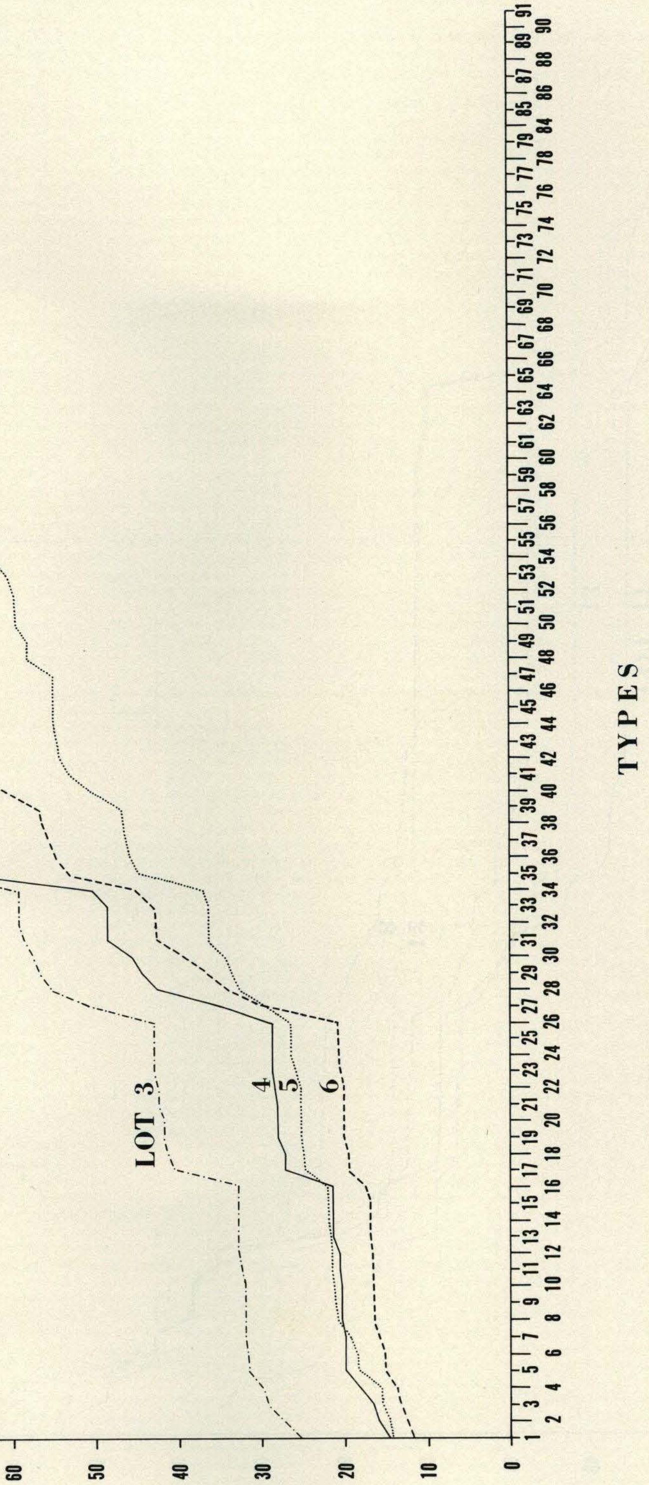

Figure 17. *Ogives for Cluster A, Lots 3 through 6*

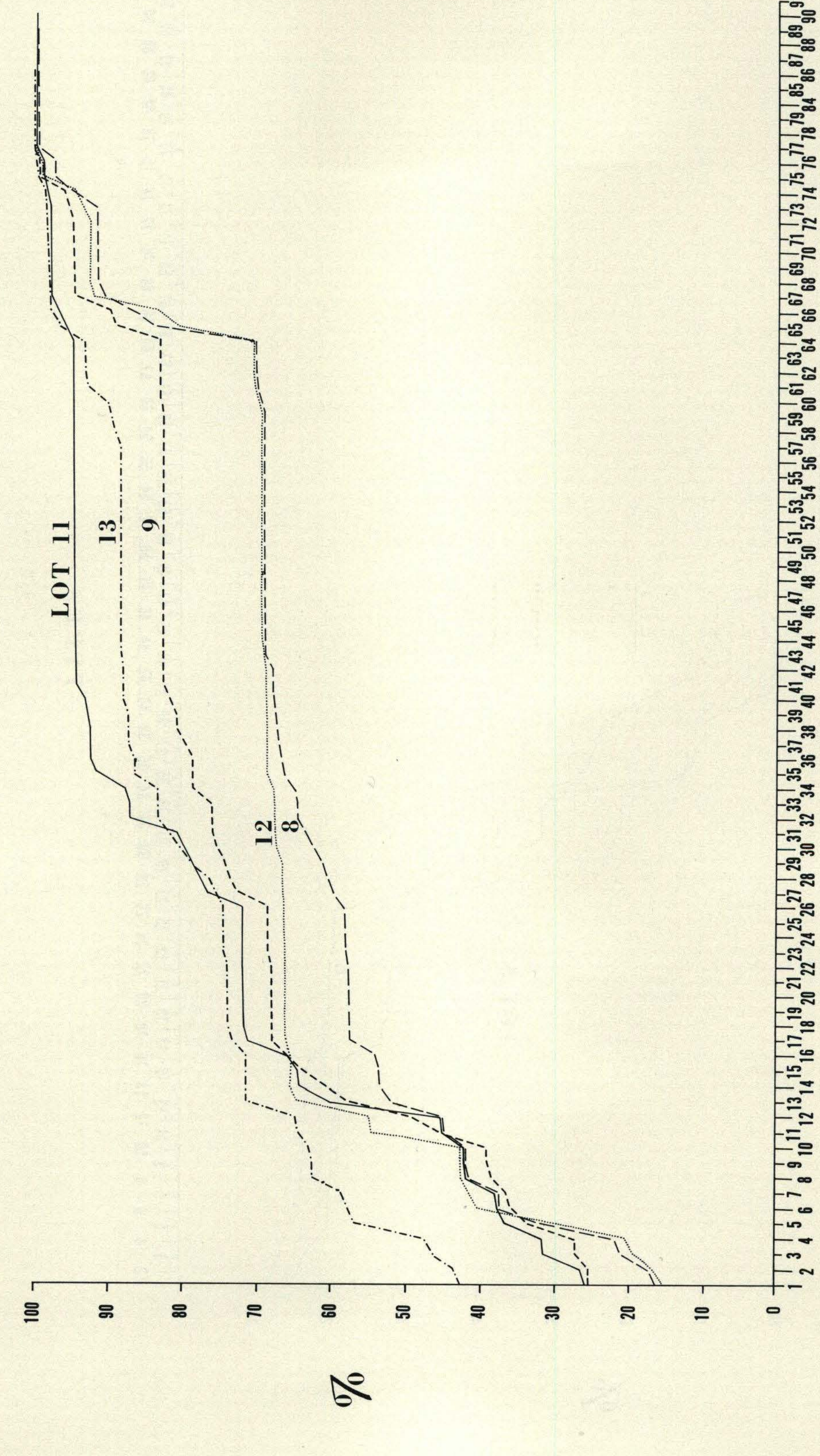

Figure 18. *Ogives for Cluster B, Lots* 8, 9, 11, 12, 13

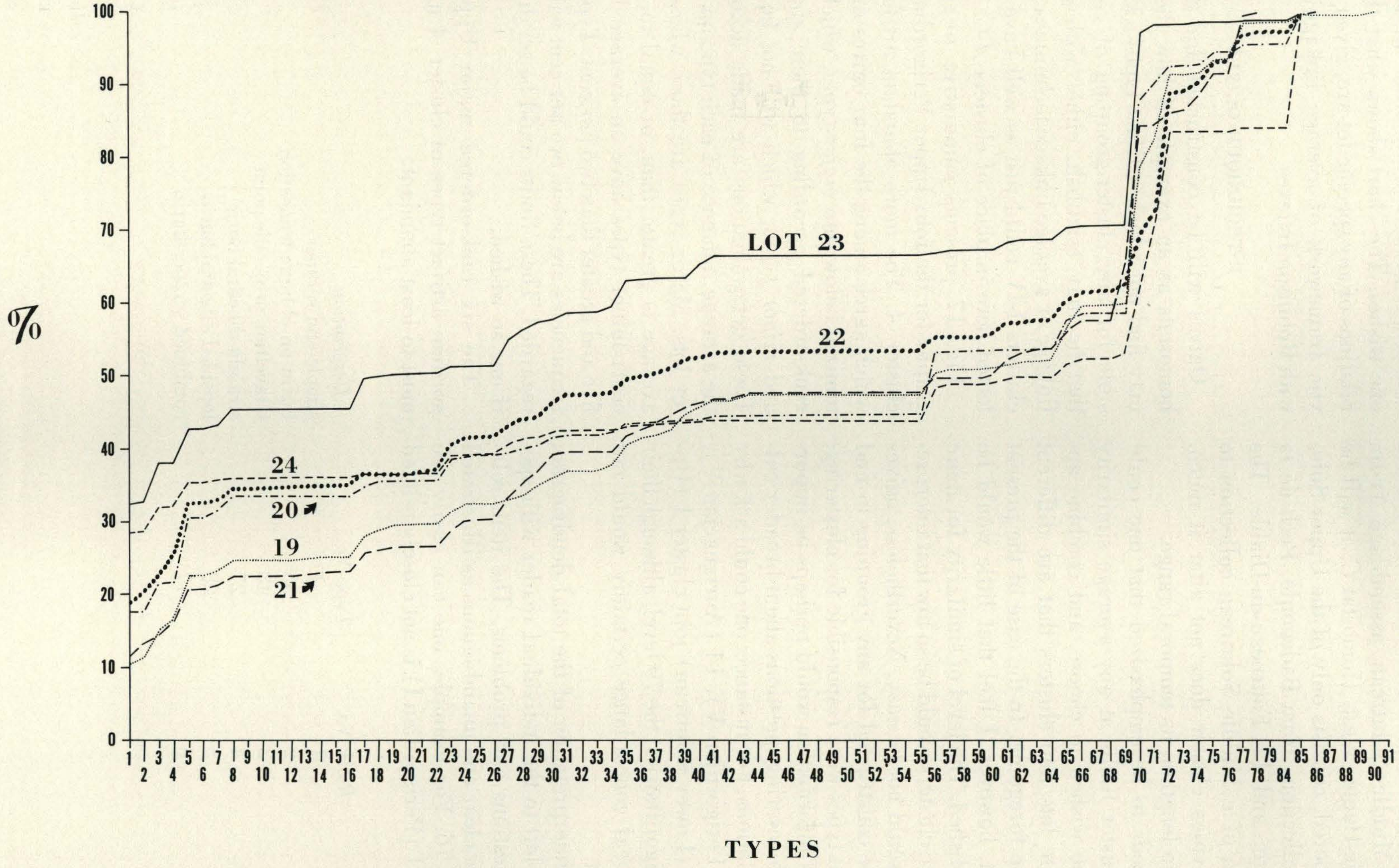

Figure 19. *Ogives for Cluster C, Lots* 19 *through* 24

Cluster IV agrees with homostat *C* except that it contains a new collection, lot 18, which is the Middle Solutrean assemblage from Laugerie-Haute, West. Homostat *C*, it will be remembered, consists only of the Upper Solutrean collections from Badegoule, Pech de la Boissière, and Le Fourneau-du-Diable. The addition of a Middle Solutrean collection to the previous cluster does not alter it much, except to lengthen its temporal range.

It needs to be emphasized that one could reset cluster limits at any average similarity value he wished to choose, and combine appropriate lots into clusters that are different from the foregoing. In the case of the present data set, however, I feel that little would be accomplished. The level of similarity for more inclusive clusters would be so low that interpretation would not be easy. Nevertheless, ogives could be constructed for any grouping to find out what types were responsible for clustering, and this information would perhaps be important in answering questions about broader cultural relations. For instance, one could ask why lots 7 (Perigordian V), 14 (Aurignacian V), and 15 (Lower Solutrean) join cluster I (Upper Perigordian) at the 79 level, although their typological concordance certainly would not be great.

The interpretation of the total dendrogram will be left to the individual reader with specific questions and problems. The item relations are clear and unambiguous as illustrated in Fig. 16. For example, one can easily see that lot 1 (Perigordian I) is not closely related to any other collections, and comparisons like this can be made for any other lot or lots, as one wishes. The chart shows what the major relations of any specific lot are, given the analytic framework of average linkage analysis with Robinson Indexes.

R-TECHNIQUE OGIVES

Ogives will be constructed for the three homostats as an example of how the analyst may find out which artifact types are responsible for any cluster-grouping of collections that he may establish, either with complete linkage or average linkage techniques. Clearly, clusters I-IV could just as well have been selected here in place of clusters *A-C*.

Fig. 17 presents cumulative percentage graphs for the four Upper Perigordian lots of cluster *A*. The more abundant artifact types which agree among the four ogives are dichotomized below into *major types*, which will be rank-ordered according to their abundance, and *minor types*, which will not be ranked. These determinations are made according to the average influence of each type on the cluster lots. Major types are those whose cluster average is greater than, or equal to, five per cent; minor types have an average less than five and greater than two per cent. Types whose frequencies are below two per cent will be disregarded. These limits could be set differently if one so wished.

The six rank-ordered major Upper Perigordian artifact types of cluster *A* are, from most to least abundant:

Rank No.	*Type No.*	*Description*
1	1	simple end scraper
2	35	burin on oblique truncation
3	48	Gravettian projectile point
4	27	straight dihedral burin
5	28	lopsided dihedral burin
6	17	combined scraper-burin

In addition, there are nine unranked minor types:

Type No.	*Description*
5	retouched blade scraper
29	corner dihedral burin
30	corner burin on break
31	multiple dihedral burin
40	multiple burin on truncation
41	"mixed" multiple burin
65	blade with continuous retouch on one edge
66	blade with continuous retouch on two edges

The ogives for the five Aurignacian lots of cluster *B* are superimposed upon one another in Fig. 18. The six major artifact types, rank-ordered from most common to least common, are

Rank No.	*Type No.*	*Description*
1	1	simple end scraper
2	13	muzzle-shaped scraper
3	5	retouched blade scraper
4	65	blade with continuous retouch on one edge
5	11	carinate scraper
6	6	scraper on Aurignacian blade

The nine unranked minor types are

Type No.	*Description*
3	double scraper
8	flake scraper
14	flat muzzle-shaped scraper
17	combined scraper-burin
27	straight dihedral burin
30	corner burin on break
66	blade with continuous retouch on two edges
67	Aurignacian blade
75	denticulate tool

Fig. 19 gives the cumulative percentage graphs for the Upper Solutrean collections of cluster *C*. The four major artifact types, rank-ordered in the way described above, are

Rank No.	*Type No.*	*Description*
1	1	simple end scraper
2	70	laurel leaf projectile point
3	72	typical Solutrean shouldered projectile point
4	5	retouched blade scraper

The 11 unranked minor types are

Type No.	*Description*
3	double scraper
8	flake scraper
17	combined scraper-burin
23	drill (borer)
27	straight dihedral burin
35	burin on oblique truncation
56	atypical shouldered projectile point
65	blade with continuous retouch on one edge
71	willow leaf projectile point
77	side scraper
85	backed bladelet

ARCHAEOLOGICAL CONSIDERATIONS

Before offering a few simple interpretations of the overview of the Upper Paleolithic of southwestern France acquired by item seriation and cluster-classification, the goal of the study of this data set needs to be stated again. The aim is to select and use appropriate techniques for reducing masses of minutiae to the simplest possible statement of important relations. Appropriate *Q*-technique studies are followed by *R*-technique analyses. There is no implication, no covert intent, to negate the important detailed comparative studies of tool forms, manufacturing traditions, and so forth, that have been and are being carried out on the French artifact collections. Their results are of high value. For example, there is no doubt that the Lower and Upper Perigordian represent a single tool manufacturing tradition, although the present study does not group them together.

My contention is that it is *also* very useful to get simple overviews of data relations, and to try to determine why patterns of similarities exist at this higher level of abstraction. The use of Robinson Indexes of Agreement in seriation and in clustering studies makes it possible to determine which tool forms are causing intercollection similarity, where "similarity" is defined as tool dominance or popularity. François Bordes' and D. de Soneville-Bordes' use of tool indexes and collection ogives is an attempt to do approximately the same sort of thing.

The interpretation of tool dominance is partly a functional one. That is, the similarity of site collections based on similar dominance of tool types suggests *both functional and historic* (cultural-idiosyncratic) *agreement between them.* Before going further, it will be helpful to set the stage.

The Upper Paleolithic is clearly a single cultural entity when viewed in terms of the foregoing Mousterian and the succeeding Mesolithic cultural complexes, whatever groupings may occur within it. The distinctions between Upper Paleolithic cultures are partly stylistic, but also partly functional. But in all the Upper Paleolithic of southwestern France we find an emphasis on bone and horn tools, on small stone artifacts, on the rapid manufacture of tools as opposed to the careful resharpening of old tools, on a general absence of massive choppers and cleavers, and upon the use of many very specialized artifacts, all of this tightly woven into a basic economic fabric of hunting large migratory game animals.

As presently understood, the earliest Upper Paleolithic, Perigordian I, may possibly have developed locally from a Mousterian base (Pradel 1966). The origin of the Aurignacian is less clear, but apparently the Perigordian and Aurignacian existed contemporaneously (somewhere!), perhaps as part of an area co-tradition like the Anasazi-Hohokam of the U.S. Southwest (Smith 1966). However this may be, the Aurignacian and Perigordian (including Perigordian I) seem to be independent of each other, without strong mutual influences (de Sonneville-Bordes 1960). Also, the clear technical agreement between the Lower and Upper Perigordian would indicate that the Perigordian and Aurignacian evolved separately but at the same time. Some investigators, however, hold that the Aurignacian and Late Perigordian are basically one tradition (Laplace 1958-61), a thesis hotly denied by others (Bordes 1963).

The Solutrean is still viewed as a culture whose origins are unclear. It is different from the rest of the Upper Paleolithic, but represents no real rupture in the cultural sequence as was once thought. It may have developed from earlier French cultures, perhaps from a generalized Aurignacian of the lower Rhône Valley, or may even have been introduced from Eastern Europe. At any rate, it appears in its most consistent form in the Dordogne area, whence it spread slowly outward to other regions (Smith 1966).

The following conclusions will be divided into *general* and *specific* interpretations. The former have to do with broad questions in general culture history; the latter will concern tool use and inferred economic activities.

GENERAL INTERPRETATIONS:

1. The seriation study shows that there is no overall uniform or gradual local development within the 26 lots of the type necessary for relative dating with seriation (Robinson 1951, Brainerd 1951). If the sample can be considered as an approximately accurate representation of the pre-Magdalenian Upper Paleolithic of southwestern France, this would confound any idea of local (Dordogne) origins for all the cultural units, and of their *in loco* development one from another. Outside areas must be taken into account in any explanation of origins.[4]

Desmond M. Collins' (1965) recent seriation study of some of the collections analyzed here yielded rather similar results, and should be consulted by the interested reader. One of his general findings is that collections from a broad area, larger than his Vézère Valley example, do not seriate well in terms of their known age. He infers that only a continuity of assemblages of a particular sub-area and ethnic group will chronologically seriate. If so, his data and mine can be used to infer the existence of local ethnic groups with some isolation (segregation) one from another, at least enough to make cross-group chronological seriation difficult.

2. There is evidence that several lots can be grouped into clusters on the basis of their sharing the same artifact types *in similarly high proportions*. The three homostats that have been defined are clusters *A* (Upper Perigordian), *B* (Aurignacian I, II, IV), and *C* (Upper Solutrean). The recognition of clusters *A* and *B* may be used as evidence against the thesis that the Aurignacian and Upper Perigordian are basically similar (Laplace 1963), although specific technical resemblances can be pointed out. Furthermore, it is important that clusters *A* and *C* represent only one historic segment, or period, of the Perigordian and Solutrean, respectively, illustrating a certain strong dissimilarity between their early and late manifestations. On the other hand, the makeup of cluster *B* means that "Aurignacianness" is a more uniform thing from one period to another, insofar as uniformity of the kind measured by the Robinson Index of Agreement is concerned. Four average-linkage clusters can also be defined, but their interpretation is not significantly different from that offered for the above homostats.

SPECIFIC INTERPRETATIONS:

1. The Upper Perigordian of cluster *A* is characterized by the following major tools, in order of abundance in their collections: the end scraper, burins on oblique truncation, the Gravettian point, straight and lopsided dihedral burins, and the combination scraper-burin. Minor forms, listed previously, include retouched blade scrapers, various burin types, retouched blades, and backed bladelets. This

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[4] See footnote, p. 31.

division of tool forms makes it possible to say something about economic activities and their relative importance in the living sites, in addition to defining the archaeological cluster in useful stylistic terms. The artifacts bespeak, by and large, the killing and processing of large Pleistocene game animals known from associated faunal remains. We would indeed expect to find that projectile points, scrapers, knives, and bone-working tools such as burins would be dominant in the site inventories.

It is noteworthy that the knife types (retouched blades and backed bladelets) are not among the major artifact forms. Apparently, many more scrapers than knives were needed for site-linked tasks, such as hide preparation. It is to be expected that major butchering activities—in which knives would be used for skinning, quartering, and cutting—took place at the kill sites themselves. The scrapers, on the other hand, are simply made tools that probably dulled quickly, were resharpened several times, finally discarded, and new ones rapidly made. The large numbers of burins, which also were easily and frequently replaced, were used with the groove and splinter method to work bone into effective tools. (Two parallel cuts were made in horn or bone and a splinter was detached and made into a projectile point, awl, or other tool.)

In brief, we can postulate that the dominant tools indicate that activities at living sites probably involved a great deal of hide defleshing, hide trimming, and the preparation of bone and horn artifacts. The dissecting of carcass parts and carving flesh for food, with knives, did not produce large quantities of these artifacts.

The abundance of Gravettian points is clearly an indicator of hunting, the prime activity which took place away from the rockshelters and caves. An additional suggestion is that, with the exception of the Gravettian points and burins, the major tool types are the forms most likely to be used in women's activities centered in, or near, the caves and rockshelters, while there is perhaps a likelihood that more of the minor tool forms were connected with male-dominated activities away from the living stations (skinning, quartering, etc.) and with tool manufacture (especially with burins) at the living sites.

2. The Aurignacian of cluster *B* has as its major types the simple end scraper, the muzzle-shaped scraper, the retouched blade scraper, blades with a single retouched edge, the carinate scraper, and the Aurignacian blade scraper. This assemblage is seemingly indicative of local hide preparation (scrapers) and hide trimming as well as flesh carving (retouched blades), all likely women's activities. Although no stone projectile point forms are present in this list, we have to keep in mind the heavy Aurignacian reliance on bone projectile points which are not considered in this study.

The minor tool forms—especially the two burin types and the two-edged retouched blades—are perhaps more indicative of male activities than female-dominated tasks, both at, and away from, the living sites, although this is suggested only as a general tendency. Other minor tool types are double scrapers and flake scrapers, combination tools, and denticulate artifacts.

3. The Upper Solutrean, cluster *C*, has only four major tool forms: the simple end scraper, laurel leaf and shouldered projectile points, and the retouched blade scraper. This small number of major types is partly a function of the occurrence of large numbers of specialized Upper Solutrean tool types in the sites. It is interesting that both hunting weapons (projectile points) and simple utilitarian tools (scrapers) constitute the dominant types of artifacts. The minor forms include other scraper and point forms, several burins, the stone borer, one-edged retouched blades, and the backed bladelet.

Activities both distal and proximal to living sites would seem to be indicated in this assemblage. They can be inferred, as in clusters *A* and *B*, to be hunting, meat and hide preparation (including the manufacture of clothing), and the production of bone and antler artifacts.

The foregoing interpretations of French archaeology are not new. But they are the *main* observations, I think, that may be made by getting a simple overview of data relationships with percentage-based statistics. My purpose is to illustrate what kind of determinations can be made, not to do an exhaustive study of the 26 archaeological collections. It will be easy for the reader with specific questions in mind to use the foregoing graphical and statistical data to come up with further interpretations in response to his own questions. D. de Sonneville-Bordes (1960: vols. I and II) conveniently gives all the percentage data that would be necessary to draw new ogives for lot combinations different from the ones that were made above. The seriated lot array and the tree diagram suggest many more potentially meaningful lot combinations than I have made. For instance, if the reader wished to know how lots 25 and 26 differ from the other Upper Solutrean lots of cluster *C*, he could construct ogives for the two collections and superimpose them on Fig. 19 and determine where the agreement and disagreement lies. It is hoped that further use will be made of the present data condensations.

SERIATION GENERALLY

There is such a strong trend among archaeologists and others to view seriation only as a technique for relative dating that the point needs to be made as strongly as possible that seriation is *not* primarily a dating method. Seriation is elementary similarity scaling, nothing else. It places items in positional series, unidimensionally, so that the location of any item relative to the others is a reflection of its degree of similarity to all other items in the data set. Seriation is descriptive analysis.

Data interpretation is a separate matter. Once a data set has been seriated properly, the investigator may then try to determine what would best explain differences in item positions. Shifts through time in the relative dominance of artifact types may be involved in the explanation, but so may other factors. Differences between collections may be due to site specialization: to different economic tasks, with associated tool kits, represented by the artifact assemblages. Or some sites may represent contemporaneous, but different, historic traditions and yet be similarly specialized. The archaeologist has to know a great deal about his area before he can begin making these kinds of interpretations. Seriation is helpful to him, however, because it gives an overview of item relations and facilitates the organization of interpretations. When cluster tests are applied to seriated data, patterns emerge which further aid interpretation.

I wish to point out that the recent general work on seriation by Frank Hole and Mary Shaw (1967) falls directly into the jaws of the "relative dating fallacy." There are many fine aspects of their study, however, and I do not wish to criticize it generally. Nevertheless, the emphasis is strictly directed toward a conception of seriation as relative dating, when it is really nothing more than descriptive similarity scaling.

Interestingly, Hole and Shaw attack Kuzara *et al.* (1966) for attempting to find the best ordering inherent in a data set, in accordance with a best-fit seriation model, instead of predetermining the position of collections whose temporal relations may be known beforehand. Hole and Shaw argue that the investigator should first put the items in a preliminary series: for example, a guess at the correct chronological order. This is twaddle! What must be done is to separate description from interpretation. If Hole and Shaw want to alter positions in an item permutation once the data set has been seriated, that is their option. But they lose the benefits of seriation as a *description of item relations according to a best-fit model* when they fiddle with their data too soon. The general discussion of seriation by Kuzara *et al.* (1966) is much more to the point than that published by Hole and Shaw (1967). From the foregoing it should be plain that item seriation can be considered a dating technique only in certain specific instances, where much is known about inter-lot differences and their explanation.

With the description vs. interpretation problem in mind, it is instructive to recall the disagreement between A. L. Kroeber and Stanislaw Klimek (a pupil of Czekanowski) having to do with Klimek's (1935) historical interpretation of California ethnographic data. Klimek intercorrelated tribes and clustered them into groups by means of a homostat search within a seriated item matrix. Then he correlated and clustered the traits, too, thus using both *Q*-and *R*-technique approaches. Finally, he correlated clusters of tribes with clusters of traits. Harold Driver (1962) presents the issues of the Kroeber-Klimek debate perfectly, and will be quoted at length. His ending sentence is specially applicable to Hole and Shaw's view of seriation.

> Klimek's historical reconstruction . . . differed so much from Krober's view that the latter wrote four pages in a preface to Klimek's (1935) work in order to keep the two sets of interpretations separated. This example emphasizes an important point. Two or more researchers, working with correlation methods from the same corpus of data, are likely to show a high degree of agreement in the clusters of tribes or traits they discover, yet may differ considerably in the historical inferences drawn from the clusters. The objective part of the procedure is the taxonomy [*classification*], not the historical inferences derived from it. Therefore, a culture area scheme which claims to be only a taxonomy is likely to be more objective and demonstrable than one which is thought to be historical or genetic. Kroeber's insistence . . . that culture area classification [*or an insistence that archaeological seriation*] must reflect historical factors introduces a subjective element which leaves room for disagreement (Driver 1962: 17).

ACKNOWLEDGMENTS

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