SCHIDLOWSKY, V. 1989. L'industrie lithique en obsidienne de Bahia Colorada (Patagonia): Recherche des comportements technoéconomiques. Mémoire de Maitrise, Université de Paris 1, Pantheon-Sorbonne, France.
THOMAS, D. H. 1975. "Non-site sampling in archaeology: Up the creek without a site?," in *Sampling in archaeology.* Edited by J. W. Mueller, pp. 61–81. Tucson: University of Arizona Press.
VIGNATI, M. A. 1934. Resultados de una excursión por la margen sur del río Santa Cruz. *Notas Preliminares del Museo de La Plata* 2:77–151.
WOBST, M. 1983. "We can't see the forest for the trees: Sampling and the shapes of the archaeological distributions," in *Archaeological hammers and theories.* Edited by James A. Moore and Arthur S. Keene, pp. 37–85. New York: Academic Press.

Representing and Computing Kinship: A New Approach[1]

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The study of kinship is hampered by the lack of a common language of description for basic structures and processes in the formation of kinship relations. This paper is an attempt to develop such a representational language. The conventional approach to kinship and marriage, the genealogical diagram, which represents marriage and parent/child relations between individuals, reinforces an ego-centered view of kinship and is largely unworkable as a means of analyzing kinship. Problems of presenting and analyzing data using conventional genealogies have led to attempts to stylize and simplify patterns in kinship and marriage in terms of abstract models and vocabularies that are often at considerable variance from the data. In consequence, anthropological discourse on the subject tends to involve disagreement over interpretations and ambiguous definitions. Nonetheless, there remains an urgent need to provide better means of carrying out one of the fundamental tasks of anthropology—understanding marriage and kinship as organizing principles. The tools which make it possible to give an account of kinship—a language of description for kinship and marriage—are much in need of repair.

Although the standard genealogical diagram seems a neutral enough device to represent individuals, their marriages, and their offspring, it has an inbuilt methodological individualism in keeping with the dominant social, political, and economic theories of the Anglo-Saxon world. Anthropologists continue to use such charts as primary tools for summarizing field data even though they are highly confusing when used as a means of showing elements of the social structure of communities or of families linked by intermarriage or common ancestries. The genealogical chart is somewhat analogous to the Ptolemaic representation of rotation about the Earth that had to be abandoned centuries ago in the face of conflicting evidence.

A second method that is better suited to the transcription of the basic facts of matings, marriages, and parentage (Jorion and Lally 1983, Jorion 1984) is the P graph. It captures the fundamental sociological fact that individuals connect their parents' mating (family of orientation) to their own (family of procreation). While P graphs have been used to date only in the study of kinship algebras (Weil 1949, Guilbaud 1961, Lévi-Strauss 1962, Jorion and de Meur 1980), they provide a more efficient means for storing, computing, representing, and analyzing kinship and marriage data than the conventional genealogy (White and Jorion 1991). The development of the P graph provides a new standard for the analysis of kinship data, complete with a series of programs and conventions which anthropologists and other social scientists can utilize for comparative purposes and for analysis of competing theories about kinship and social organization. The examples in this paper illustrate the use of P graphs both for computing properties and structures of kinship systems and for the graphic representation of genealogical data. The principal example, while consisting of only 20 marriages, illustrates classic problems of representing the genealogies and intermarriages of family lines over time and dealing with marriage of blood relatives, polygamy and serial marriage, half-siblings, childbirth out of wedlock, etc.

THE P GRAPH AND THE ISRAELITES OF CANAAN

A genealogical chart for the myth of the patriarchal Israelites of Canaan (Genesis 21–22) (fig. 1) shows polygyny, cousin marriage, half-sibling marriage, and incest. In the patriarchal line, Abram married his half-sister Sarai. They took the names Abraham and Sarah after their covenant with Yahweh. Sarai is alternatively identified in Hebrew scholarship with Iscah, sister of Milcah. Isaac married his father's brother's son's daughter (FBSD), Esau his father's half-brother's daughter (FF*SD), and Jacob his two mother's brother's daughters (MBD). Among the collaterals, Nahor married his brother's daughter, and two daughters of Lot seduced him and bore his children. Given kinship data of this sort, real or mythological, one would like to know the

1. This work was done while White was at the Maison des Sciences de l'Homme as Directeur d'Etudes Associé, within the framework of an international and interdisciplinary working group on discrete structures in the social sciences created around the research facilities at the Maison Suger and with the support of the Ministère de la Recherche et de la Technologie. He thanks working group member Vincent Duquenne for suggestions and programming advice. The original computer work leading to the Jorion-Lally algorithm was financially supported in 1982–83 by the Nuffield Foundation; invaluable intellectual support was provided over this period by Edmund Leach and Rodney Needham. We are indebted to Françoise Héritier-Augé for suggesting possible lines for the present collaboration.

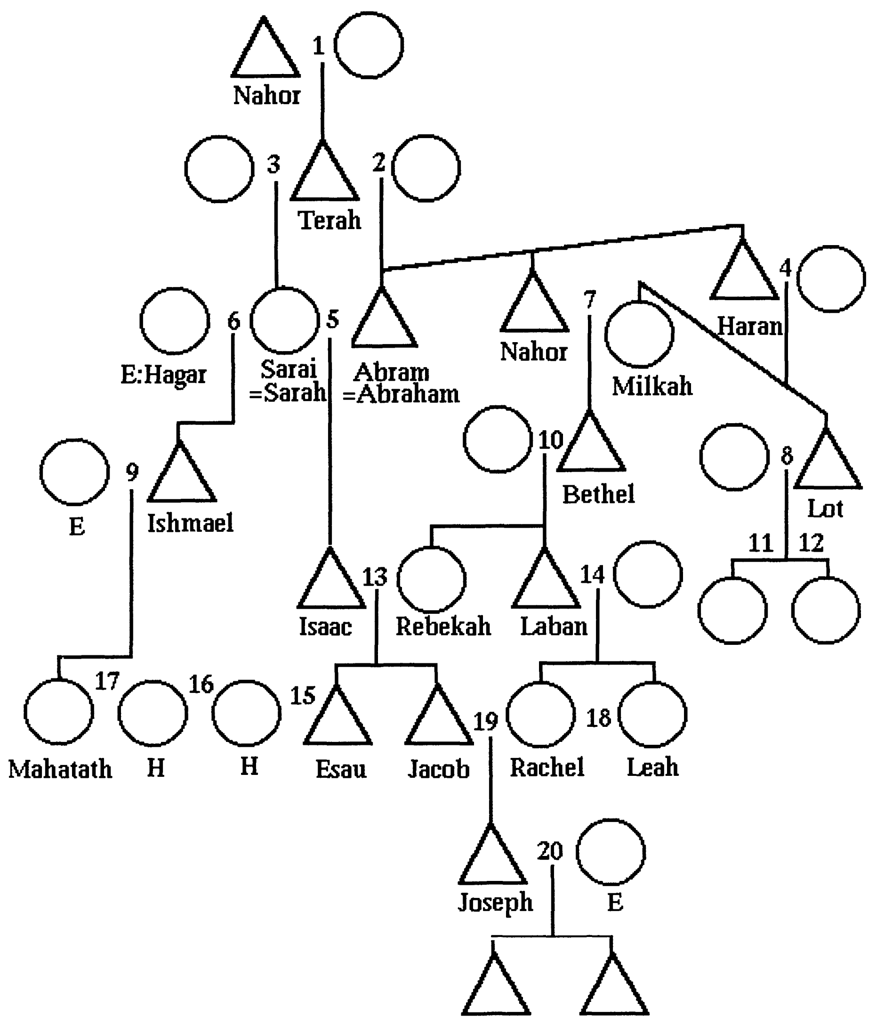

FIG. 1. *Genesis genealogy of Canaan.*

relative frequencies of different types of blood-kin marriage and identify the kinship rules that are satisfied, which typically are not unique. For example, Jacob's wives (18 and 19) are not only MBD collaterals of Isaac but patrilineal FFBSSD, as well as FMF*SSSD and FFBDSSD, codescendents of Terah. Esau's wife (17) is a patrilineal codescendent (FF*SD) of Abram and a FMF*SSD, MFMFBSD, and MFFBSD, codescendent of Terah through Abram and his brothers. Patrilineal codescent from Abram or Terah is a common pattern in most of these marriages. For large genealogies, however, the analysis of marriage patterns is not an easy matter.

A P graph has directed arrows that run downward to children or upward to parents (fig. 2). The arrows are of two types, one for males (here solid) and one for females (here dotted). (Signs for gender may change as a matter of emphasis.) The downward meeting of two lines represents a parental mating or marriage. The meeting of two lines upward denotes common parentage not for the couples below but for the gendered persons represented by the lines. A P graph is drawn using output of the parental graph program (PAR-GRAF) (written by DRW) to create laser printer commands in the Hewlett-Packard Graphics Language (HPGL). (The program to convert output to HPGL format was written by DRW and Linton Freeman.) Points representing parental matings are arranged by generation. Couple 7 in figure 2, however, is both one and two generations below 2, as are 11 and 12 below 4. Polygamous individuals (in this case males) are represented as multiple lines from the same parents connected by a horizontal line; they are also denoted by the names associated with the couples under the lines for these individuals. Terah, Abram, and Jacob have two wives each, Esau three, and Lot three (counting his daughters). Patriarchal succession (Nahor to Terah to Abram to Isaac to Jacob to Joseph) is shown by the principal vertical axis. Parental couples represented by dark circles are in the line of succession; couples represented by white circles include eldest sons who should have inherited (by primogeniture) but did not. The collateral lines, such as those of Ishmael and Esau, become ruling houses in lands outside Canaan.

We see from the P graph that where there are elder and younger sons, in no case does the elder succeed normally to patriarchal headship. Typically, the mothers or wives of the eldest sons are women from foreign groups

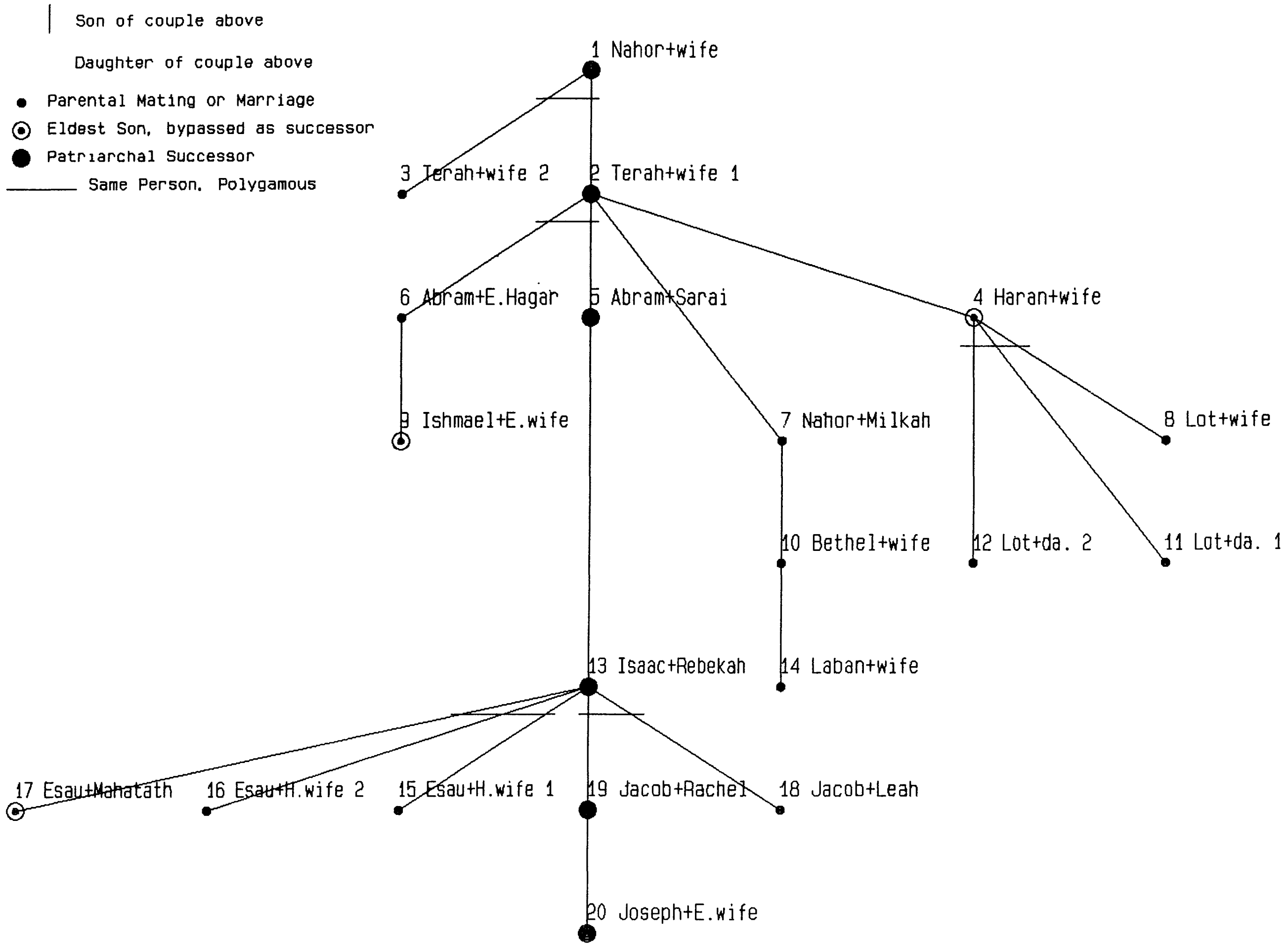

FIG. 2. *Marriage and succession in the Genesis genealogy of Canaan.*

(Egyptian or Hittite; Haran's wife's origin is unknown), whereas the younger sons who do succeed have mothers and wives from within the lineage. The Old Testament cites Esau's failure to take a wife from the patriarchal line in his first two marriages as one reason he was passed over in the succession. He was ordered to make a proper third marriage and did so with Ishmael's daughter Mahatath. The pattern of marriage with Egyptians and Hittites, which continues as a means of consolidating alliances with neighboring kingdoms through later generations, sets the stage in the Old Testament for the interdiction of outside marriages.

What is particularly significant about P graphs for our purposes is the ease with which they may be analyzed computationally. A vectorial representation is obtained by numbering each marriage (e.g., as in figure 1, from 1 to 20) and listing under it the marriage numbers of the husband's and wife's parents (table 1). For marriage m_j in a series of marriages $m_1, \ldots m_k$, numbered $1, \ldots, j, \ldots, k$, the husband's parents' marriage number is assigned to $G(j)$ and the wife's parents' marriage number to $F(j)$. Functions G and F thus assign the unique value of husband's and wife's parents' marriage numbers, respectively, to each marriage. Ancestors are designated

TABLE 1
Vector Genealogy Input Data for Canaanite Ruling Houses

m_j	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
$G(j)$		1*	1*	2	2*	2*	2	4*	6	7	4*	4*	5	10	13*	13*	13*	13**	13**	19
$F(j)$					3		4				8*	8*	10				9	14*	14**	

* and **, identical individuals.

TABLE 2
Prior Kin Marriage Output of the P Graph Algorithm

Kinship Equation	Kin Type	Number of Couples	List of Couples
G = FG	BD	3	7, 11, 12
GGG = FGGG	FFBSSD	2	18, 19
GF = FG	MBD	2	18, 19
GGG = FGGFG	FFBDSDD	2	18, 19
GGFG = FGGGG	FMFBSSSD	2	18, 19
GGFG = FGGFGG	FMFBSDSSD	2	18, 19
GGG = FGG	FFBSD	1	17
GFGG = FGG	MFFBSD	1	17
GFGFG = FFG	MFMFBSD	1	17
GGFG = FGGG	FMFBSSD	1	17
GG = FGG	FBSD	1	13
GFG = FGFG	FBDSD	1	13
GFG = FGGG	MFBSSD	1	13
GFG = FGFGG	MFBSDSD	1	13
GG = FG	FBD	1	5

by functions such as *GGGF* for a man's FFM's parents, where *GGGF(k) = F(G(G(G(k))))*. To determine in marriage *k* whether husband and wife are related by common descent, there must be equality of some pair of functions, *G . . . (k) = F . . . (k)*. For example, since *GF*(18) = *FG*(18) = 10, couple 18 is related by common descent from couple 10 and the prior kin connection MBD/FZS.

The heart of the P graph algorithm (PAR-CALC), given *G* and *F* as input vectors, consists of tracing convergences by vectorial genealogy: BEGIN trace husbands' genealogical trees to a nonempty vector; BEGIN trace wives' genealogical trees to a nonempty vector; save convergences; continue wives' trees until done (no nonempty vectors); END; continue husbands' trees until done (no nonempty vectors); END. Results of applying this algorithm to the Canaan kinship vectors in table 1 are shown in table 2.

Direct vectorial genealogy does not, however, distinguish the paternal half-brother from a FB child (or the maternal half-sister from a MZ child). The difference is shown in the first two subgraphs of figure 3. The other two subgraphs show two cross-cousin marriage graphs. One can verify from figures 1 and 2 that F*D and MBD occur but FBD and FZD do not.

The PAR-CALC algorithm can be refined as follows to bring analytic computations into line with P graph diagrams:

1. *Sibling differentiation in multiple marriages.* Elements in vector *G* with the same number constitute a set of sons of the same parents (e.g., 13 for the sons of Isaac and Rebekah). Occurrences of the same son are identified in table 1 by asterisks: 13* for Esau (in three marriages) and 13** for Jacob (in two marriages). Similar distinctions are made for daughters (e.g., 14* and 14** for Leah and Rachel). To make these distinctions explicit, we use another data format with vectors *G** and *F** in which members of each sibling set are assigned

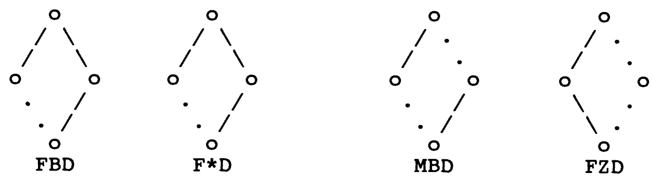

FIG. 3. *P graphs of some marriage types.*

distinct (e.g., birth order) numbers. Once a blood-kin equation is made in which the last link consists of two same-sex siblings (e.g., *GGFG = FGGGG*), *G** or *F** is checked to see if the last function in the two series (in this case *G*) refers to the same person by a half-sibling link. For example, the relation between spouses in couples 18 and 19 is not FMFBSSSD but FMF*SSSD. The data format which identifies siblings also distinguishes individuals with multiple marriages (fig. 2) but not which marriages are simultaneous (polygamous) and which are serial.

2. *Birth dates and marriage dates.* Birth dates alone, if given for children as well as for married adults, can be used to estimate the frequencies of effective serial versus effective polygamous marriages. Birth dates of children give a range of years in which couples are producing children. A person's multiple marriages can be divided into those which overlap in terms of childbirth and those which do not. Because they are useful for other purposes as well, data on birth dates have higher priority than the combination of marriage dates and dates of divorce or separation needed to establish an "official" distinction between polygamous and serial marriages. If marriage starting and ending dates are provided, a separate analysis can be done on polygamy and serial marriage by age cohorts.

3. *Birth dates and the female/male generation ratio.* Birth dates of husbands and wives, such as are available, allow computation of the average difference in age at time of marriage. Of greater significance for analyzing the structure of kinship, however, are estimates of age of motherhood (average age at which mothers have children), age of fatherhood (average age at which fathers have children), and generational age ratio (age of motherhood/age of fatherhood). The age ratio gives the relative generation time for men and women and is a fundamental structural characteristic for the analysis of rules for marriages between blood kin (Tjon Sie Fat 1983, 1990). It can be calculated from the expanded data format if birth dates are known for children.

4. *Generation ratio estimated without birth dates.* Analysis of blood-kin marriages can be used to estimate relative generation time even without knowledge of children's birth dates. If men's generation time is measured as the unit of 1 and women's generation time relative to men's is *f*, the standardized age difference at marriage is 1 − *f*. If for the closest blood relation between husband and wife we count the numbers of maternal and paternal links for each and cancel pairs that match up to the ascending sibling pair by which they are connected, a sum and average are drawn from the following estimates of the standardized age difference: add 0 if

TABLE 3
Prior Kin Marriage Output of P Graph Algorithm, Refinement 5

Kinship Equation	Kin Type	Number of Couples	% of Couples	List of Couples	Vector for Couples[a] 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
GGFG = FGGFGG	FMF*SDSSD	2	28	18, 19	. . . . – . – . . . – – – . . . . 1 1 .
GGG = FGGG	FFBSSD	2	25	18, 19	. . . . – . – . . . – – – . . . – 1 1 .
GF = FG	MBD	2	25	18, 19	. . . . a . – . . . – – 0 . . . 0 1 1 .
GGG = FGGFG	FFBDSSD	2	25	18, 19	. . . . – . – . . . – – – . . . – 1 1 .
GGFG = FGGGG	FMF*SSSD	2	25	18, 19	. . . . – . – . . . – – – . . . – 1 1 .
G = FG	D	2	25	11, 12	. . . . 0 . 0 . . . 1 1 0 . . . 0 0 0 .
G = FG	BD	1	12	7	. . . . 0 . 1 . . . 0 0 0 . . . 0 0 0 .
GFGFG = FGG	MFMFBSD	1	16	17	. . . . . . – . . . – – . . . . 1 – – .
GFGG = FGG	MFFBSD	1	14	17	. . . . . . – . . . – – a . . . 1 – – .
GGG = FGG	FF*SD	1	12	17	. . . . – . – . . . – – – . . . 1 0 0 .
GGFG = FGGG	FMF*SSD	1	12	17	. . . . – . – . . . – – – . . . 1 0 0 .
GG = FGFG	FBDSD	1	20	13	. . . . – . – . . . – – 1 . . . .
GFG = FGFGG	MF*SDSD	1	16	13	. . . . – . – . . . – – 1 . . . . – – .
GG = FGG	FBSD	1	12	13	. . . . – . – . . . – – 1 . . . 0 0 0 .
GFG = FGGG	MF*SSD	1	14	13	. . . . – . – . . . – – 1 . . . 0 – – .
GG + FG	F*D	1	12	5	. . . . 1 . – . . . – – 0 . . . 0 0 0 .

* Related through a different spouse than ego.
[a] *1*, present; 0, absent; *a*, inferred absent; –, absent because there is a closer relation within the kin type; ., impossible to determine.

each has the same number of extra elements; add 1 for each extra *G* link of the wife; add *f* for each extra *F* link of the wife; subtract 1 for each extra *G* link of the husband; subtract *f* for each extra *F* link of the husband; add $1 - f$ for each MB link in the sibling generation. There will exist a solution for *f* except where all marriages are of equal generational descent from a MB sibling pair. With data on children's birth dates this estimate can be compared with the actual value. For the eight consanguineally linked couples in figure 1 (5, 7, 11–13, 17–19), the average estimate of generational age difference $(1 - f) = 6f/8$ and consequently $f = 4/7 = 0.57$. The average female reproductive age is 4/7th that of the male by this estimate. This is consistent with the relatively high rates of polygyny observed.

Tjon Sie Fat (1983, 1990) and Jorion (1982) discuss systems of generational exchange or cycling marriages between lineages in which the metric for the different generational intervals for males and females is consistent with different types of marriage rules. Although Canaanite kinship does not fit a model of repetitive generalized exchange, the age metric computed above is close to $f = 0.50$, for which there are age-biased marriage-system models with matrilateral (MBD) marriages. The simplest abstract model for $f = 0.50$ (Jorion 1982:6; Tjon Sie Fat 1990:162) is a single matriline in which brothers marry their sisters' daughters, who are also MBDs. In such a system there are two patrilineages, two male generations of wife giving from A to B to A in alternate generations. A system of this type (depending on consistency between age bias, number of lineages, and length of cycles) might conceivably emerge with the establishment of ruling and collateral lines as the house of Canaan develops more generations and more collateral lines. Because we see a pattern whereby alliances with lines in other kingdoms for eldest sons alternate with lineage endogamy for younger sons, however, no single marriage rule is established.

5. *Percentage of marriages for blood-kin types.* Given a potential marriage rule between spouses such as MBD/FZS, sufficient genealogical information exists for deciding whether a couple's marriage satisfies the rule if (1) both parents of the ascending collaterals (such as husband's MB and wife's FZ) are known or (2) one of the parents of the ascending collaterals is known and the next lower ascending ancestors (such as husband's M and wife's F) are known for both. For couples 18 and 19 in figure 1, for example, there are MBD/FZD marriages by rule 1, and we can infer the absence of FZD/MBS marriage by rule 2, since husband's F is not wife's MB.

Table 3 is a P graph program (PAR-CALC) output that gives each type of prior consanguineal kin connection, the number of couples with this prior kin relation, the percentage of couples for which relevant information exists which have this prior kin connection, a list of such couples, and a vector in which the entry for each couple indicates wherever possible the presence or absence of this type of marriage. Any couple (such as 18 and 19) related in multiple ways will recur on two or more of the lists of couples. From the P graph we see a tendency for patrilineal descendents of patriarchs to marry female patrilineal descendents and for the type of realization of endogamous patrilineal preference to change across the generations: Abram marries a half-sister (F*D) and his brother Nahor a niece (BD); Esau marries a first cousin (FF*SD) and Isaac a first cousin once removed (FBSD); Jacob marries a patrilateral second cousin once removed.

6. *Longitudinal analysis of patterns through time.* The P graph in figure 2 shows a typical feature of kinship systems—that there are no absolute generational levels

TABLE 4
Prior Kin Marriage Output of the P Graph Algorithm, Refinement 6

Kinship Equation	Kin Type	Generation	Number of Couples	% of Couples	List of Couples	Vector for Couples[a]: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Abram-Nahor-Haran		3	2	100	5, 7	.	.	.	.	1	.	1													
GG = FG	F*D	3	1	50	5		.	.	.	1	.	–													
G = FG	BD	3	1	50	7		.		.	0	.	1													
Lot-Ishmael-Bethel		2	2	100	11, 12								.	.	.	1	1								
G = FG	D	2	2	100	11, 12									.	.	1	1								
Isaac-Laban		1	1	100	13													1	.						
GFG = FGFGG	MF*SDSD	1	1	100	13													1	.						
GFG = FGGG	MF*SSD	1	1	100	13													1	.						
GG = FGFG	FBDSD	1	1	100	13													1	.						
GG = FGG	FBSD	1	1	100	13													1	.						
Esau-Jacob		0	3	100	17, 18, 19															.	.	1	1	1	.
GGFG = FGGFGG	FMF*SDSSD	0	2	100	18, 19															.	.	.	1	1	.
GF = FG	MBD	0	2	66	18, 19															.	.	0	1	1	.
GGFG = FGGGG	FMF*SSSD	0	2	66	18, 19															.	.	–	1	1	.
GGG = FGGFG	FFBDSSD	0	2	66	18, 19																.	–	1	1	.
GGG = FGGG	FFBSSD	0	2	66	18, 19															.	.	–	1	1	.
GGFG = FGGG	FMF*SSD	0	1	33	17															.	.	1	0	0	.
GGG = FGG	FF*SD	0	1	33	17															.	.	1	0	0	.
GFGFG = FGG	MFMFBSD	0	1	33	17															.		1	–	–	.
GFGG = FGG	MFFBSD	0	1	33	17															.	.	1	–	–	.

*Related through a different spouse than ego.
[a]1, present; 0, absent; –, absent because there is a closer relation within the kin type; ., impossible to determine.

for individuals: Joseph, for example, is a generation 3 descendent of Terah through Abram but a generation 4 descendent through Abram's brother Nahor. Similarly, Bethel is Terah's grandson through his father but a great-grandson through his mother. As a result, it is usually preferable to use historical time based on birth, marriage, and death dates and to trace kinship connections for a given cohort. In this example, even without specific birth dates, computations for four generational periods as given by the program (PAR-CALC) are shown in table 4. Percentages of blood-kin marriage increase relative to those in table 3, because the baseline vector for comparison of frequencies is now the specific generational cohort. All marriages in the first and second periods (Abram-Nahor-Haran-Lot) are with first-degree patrilineal relatives, all marriages in the third with second-degree patrilineal relatives, and all marriages in the fourth with third-degree patrilineal relatives. In the last two generations these ties are reinforced through numerous other blood relationships.

7. *Types of polygyny.* Sororal polygyny computes as *F(i) = F(j), G(i) = G(j)* and *G*(i) = G*(j)* where *i$j* (WZ = W*, where W*$W). In nonsororal polygyny *G(i) = G(j)* and *G*(i) = G*(j)* but *F(i)$F(j)*.

IMPLEMENTATION OF THE PGRAPH PACKAGE

An implementation of the PGRAPH package of programs is available from DRW or *World Cultures*.[2] For both PAR-CALC and PAR-GRAF, alternative formats for input files are (1) P-DAT.VEC, which has only the *G* and *F* vectors for parents or marriages numbered 1 . . . *k*, a format for the option of giving *G** and *F** vectors, and a vector of identifying numbers which may correspond to some external dataset; and (2) P-DEMOG, with arbitrary marriage numbers, *G* and *F* vectors stated in terms of these numbers, optional *G** and *F** vectors, birth and death dates of husband and wife (and children's birth dates under separate numbers), starting and ending dates for the marriage, and husband's and wife's names.

Output from PAR-GRAF consists of the kinship net graphic shown in figure 2. PAR-CALC output is given in three formats, the most basic of which is shown for Canaanite kin relations in table 3. PAR-CALC also runs a subsidiary program, PAR-CAL2, that computes a marriage network of kinship links as a second output (table 5). The graph of this matrix (like figure 2) is transitive. Two matrices are in fact given, the first for the consanguineal core, which includes kin-related couples and those who link other couples on kin-related paths. In the core matrix a given couple may be related in multiple ways by different common ancestral paths in the graph of this kin network. A second matrix includes those outside the core network, such as couples 16, 17, and 20 (table 4), who have at most only one consanguineal connection to those in the core network. The third PAR-CALC output is a condensation of the first format, eliminating couples for which there is no information on blood relationships (table 6).

2. For distribution of the PGRAPH package (PAR-GRAF and PAR-CALC), contact Patrick Gray, *World Cultures* Co-Editor, Department of Anthropology, University of Wisconsin, Milwaukee, Wis. 53201, U.S.A.

OTHER APPLICATIONS AND EXTENSIONS

Multiple blood-kin types and preferential marriage. Computation of blood relationships between spouses, as

TABLE 5
Matrix Output of Common Ancestral Kinship Paths and the Larger P Graph

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18	19	16	17	20
1		1	1		1	1	*		1	1			*	1	*	*	*	1	1	1
2						2							1		1	1	1	1	1	1
3					1	1	1		1	1			*	1	*	*	*	1	1	1
4							2	1		1	*	*	2	1	1	*	*			1
5									1						2					
6													1		1	1	1	1	1	1
7										1			2	1	1	*	*	1	1	1
8											2	2								
9															2					
10													2	1	1	*	*	1	1	1
11																				
12																				
13															1	1	1	1	1	1
14																2	2			1
15																				
18																				
19																				1
16																				
17																				
20																				

CORE NETWORK

NOTE: *1*, husband of first couple is descendent of second; 2, wife of first couple is descendent of another; *, both are descendents of another marriage; 0, neither is a descendent of the other.

TABLE 6
Prior Kin Marriage Output of the P Graph Algorithm (Reduced)

Kin Type	Vector for Couples[a]							
	5	7	11	12	13	17	18	19
MBD	a	—	—	—	0	0	1	1
FFBSSD	—	—	—	—	—	—	1	1
FFBDSSD	—	—	—	—	—	—	1	1
FMF*SSSD	—	—	—	—	—	—	1	1
FMF*SDSSD	—	—	—	—	—	—	1	1
D	0	0	1	1	0	0	0	0
BD	0	1	0	0	0	0	0	0
MFMFBSD	.	—	—	—	.	1	—	—
MFFBSD	.	—	—	—	a	1	—	—
FF*SD	—	—	—	—	—	1	0	0
FMF*SSD	—	—	—	—	—	1	0	0
FBDSD	—	—	—	—	1	.	.	.
MF*SDSD	—	—	—	—	1	.	—	—
FBSD	—	—	—	—	1	0	0	0
MF*SSD	—	—	—	—	1	0	—	—
F*D	1	—	—	—	0	0	0	0

*Related through a different spouse than ego.
[a]*1*, present; 0, absent; *a*, inferred absent; —, absent because there is a closer relation within the kin type; ., impossible to determine.

in tables 3 and 4, raises the problem of how to interpret the multiple ways in which couples may be related. For example, MBD marriage is one of the more common types of marriage in table 3, but the two couples related in this way (Jacob and his wives) are also related in other ways. Couples 13 and 17 are also related in multiple ways. There is no direct answer to the question of which of these kin types, if any, represents a marriage rule or preference. We can, however, identify recurrent patterns. In the present example, patrilineal codescent is the common pattern. If i and j in F and S index the number of repetitions of patrilineal father and son links, the recurrent marriage type is $(F)iB^*(S)jD$, where (F) and (S) can be zero or repeated and B* is a brother or link through a second wife not ancestral to ego. This pattern of marriage holds for all of the blood-related couples: 5 (F*D), 7 (BD), 11 and 12 (*D), 13 (FBSD), 17 (FF*SD), 18 and 19 (FFBSSD).

Kinship models. The functions F (woman's parents) and G (man's parents) and their relational inverses, f for daughter and g for son, form a natural set of operators with which to describe kinship and marriage relations. Weil (1949) introduced the idea of the P graph as a basis for the algebraic analysis of kinship. Guilbaud (1970) developed the graphic convention for societies with prescriptive marriage rules (see Lévi-Strauss 1962:fig. 5, adapted from Guilbaud). P graph algebra has been recently used by Jorion and de Meur (1980), Jorion, de Meur, and Vuyk (1982), and Jorion (1984) for analyzing models of social systems with specific sets of marriage rules. A MBD/FZS marriage rule, for example, is one where $FG = GF$ (a man's mother's parents are a woman's father's parents; alternatively, $fg = gf$). One can construct a marriage graph in which all marriages are of this type. Given a set of rules to express that men of certain kin groups can marry only women of certain other kin groups and to assign kin-group membership to sons and daughters for each type of marriage, a P graph can be built to represent the kinship system. Jorion (1984) was the first to use P graphs to represent kin nets among specific individuals, although not with reference to specific societies. His unpublished paper with Lally (1983) was the first to propose the P graph model as a basis for computing kinship relations.

The P graph approach facilitates the comparison of kinship models and evaluation of their goodness of fit to empirical data. Choice of algebraic models may be guided by computation and comparison of the frequencies of each type of prior kin connection, the metric for female/male generational age ratio (and congruent evidence from number of lineages, length of marriage cycles, etc.), the empirical P graph for the population, and the analysis of the graph in matrix form, as well as suggestions about kin-type equivalencies derived from kinship terminologies. Algebraic simplifications can be tested on the underlying empirical graph if the original data are available.

Analyses of kinship links. As Jorion, de Meur, and Vuyk (1982) have shown for the Pende, there exist societies in which many, most, or all instances of a particular marriage type derive this relationship as a by-product of a preferential prescribed marriage category of a higher order. Their model for the Pende predicts as a statistical implication that both FZD and MBD marriages imply as a superset MFZDD marriage. An empirical entailment analysis to test for such implications can be done from the rectangular matrix of kin-related couples by marriage types given as the third output of the program. White's (1985) entailment analysis package identifies statistically relevant implications which may have exceptions. In the Canaanite example, however, there are no interesting implications.

Lattice analysis (Duquenne 1991) identifies implications with zero exceptions for a set of binary data (such as table 6, dichotomized for presence/absence). When applied to the network matrix output of PAR-CALC (table 5), the lattice of a P graph contains the P graph plus additional information about the co-occurrence of multiple blood marriages. A lattice, like a P graph, is an ordering of points, but each pair of points will have a single least upper bound (join) in common and a single greatest lower bound (meet) in common. Given the four points 13, 14, 19, and 18 in figure 2, where 18 and 19 have two upper bounds and 13 and 14 have two lower bounds, a lattice analysis will create a new virtual point for the meet of 13 and 14 which is also the join of 18 and 19. The existence of such virtual points in the lattice provides a mapping of the couples involved as exchange nodes in the kinship structure.

The use of a P graph approach to the representation and computation of empirical marriage, kinship, and exchange networks opens up the study of kinship to the tools for network and structural analysis that have developed over the past several decades (see, e.g., Freeman, White, and Romney 1989 and Freeman and MacEvoy 1987). Freeman and White (1992) have identified lattice analysis (Duquenne 1991) as the best representation of structural properties of symmetric network matrices, and White and Duquenne (1991) have shown the applicability of lattice analysis to transitive graphs such as the kin networks generated by the present P graph algorithm.

Ancestral clans. The computation of kinship and marriage networks and their algebras is limited only by the extent of the genealogical data available for a given population. This may reflect limits on oral or written genealogical knowledge or the memories of individual informants. There is always the limiting case in which one or both of the parents of an ancestor are unknown. If kin-group membership data are available on these limiting apical ancestors, the P graph method makes it possible to take this into account in computing kinship connections. Although kinship is normally computed from individual genealogies, one may default to such knowledge as common clan membership when more specific individual data are unknown. This will introduce into the network a certain number of representative marriages which are for different combinations of clan types: husband of clan 1, wife of clan 2, etc. For certain kinds of societies, a network computed with clan information for apical ancestors may provide the kind of closure that

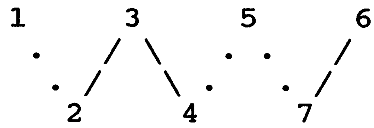

FIG. 4. *P graph of a marriage chain.*

is needed for a fuller understanding of the kinship system and its algebraic representation.

Notation for kinship relations. Because parent links and couplings are the primitives of kinship linkages, the four-term vocabulary involving operators *G, F, g,* and *f* is sufficient to describe kin relations with the addition of a minimal vocabulary to refer to individual lines in a parental graph. Let | adjacent to another symbol refer to the oriented line for an individual (*G*|, |*G*, or |*g*, etc., for males and *F*|, |*F*, |*f*, etc., for females); |*Gg*|, for example, refers to a brother-brother link. The placement of | between symbols in compound relations will refer to the co-relation between multiple spouses of the same individual, as with *G*|*g* or *F*|*f* in the relations |*fG*|*gF*| (woman's husband's co-wife) or |*FG*|*gf*| (woman's father's daughter by another marriage). All interpersonal kin relations may be written using these five symbols, and the reciprocal of any kin relation is made by simply reversing the order and (upper/lower) case of symbols.

Marriage chains and cycles. Complex marriage systems may contain chains of consanguineal and marriage links (e.g., marriage to ZHZHZ) without or in addition to couples' being related by prior consanguinity. Figure 4 shows an example of such a chain. In this case, the only output of the PAR-CALC program is contained in the matrix for the P graph (table 7). In this graph, the men of marriages 2 and 4 are brothers (|*Gg*| = B/B) and the women are sisters-in-law (|*fGgF*|/|*fGfF*| = HBW/HBW). The man and woman of 2 in relation to the man below 6 are |*GgFfG*|/|*gFfGg*| = BWZH/WZHB and |*fGgFfG*|/|*gFfGgF*| = HBWZH/WZHBW. P graphs provide an economical way of displaying complex networks of consanguineal and affinal relationships.

Endogamy and exogamy. Given a P graph as output of analysis, latent endogamous subgroups can be identified by standard network clustering procedures (Freeman and MacEvoy 1987). Latent exogamous subgroups can be identified by regular equivalence analysis (White

TABLE 7
Matrix Output of P Graph of Figure 4

	1	2	3	4	5	6	7
1		2					
2							
3		1		1			
4							
5				2		2	
6							
7						1	

and Reitz 1983, 1984). If frequencies of marriages are aggregated by either latent or manifest criteria (lineages, descent groups, or other overt social groupings), rates of endogamy and exogamy can be computed by methods developed by Romney (1971).

CONCLUSION

Among the central problems in social structure which are given a foundation via empirical computations in the P graph approach are questions about simple and complex marriage rules, incest avoidance, marriage cycles, exogamous and endogamous groups, lineage and clan organization, difference in generational time for males and females and its effect on kinship structure, effects of polygamous marriages, and change in social systems over time. Endogamy and genetic inbreeding are also of interest to physical anthropologists and geneticists.

Given that problems of representation of kinship and marriage networks are of central theoretical importance to the study of social structure, the P graph approach offers a more efficient representation of kinship than conventional genealogical trees and a more natural description of kinship relations, rules, and structures than conventional algebraic approaches. The approach provides an algorithm which not only efficiently generates for any population every path of known genealogical connections by which m pairs of spouses are kin-related but also yields a maximally reduced kin network in P graph format of common ancestries for all kin-related couples and a complete consanguineal and affinal kin network. The methodological advance is of major importance: computing P graphs from genealogical data for a population permits network and algebraic analysis of kinship based on observed data and the empirical testing of idealized or theoretical models.

In the test case of Old Testament genealogical data on the ruling house of Canaan, P graph analysis shows a strong rule for those who succeed to the patriarchy to take wives who are codescendents from the patrilines of former patriarchs. However, elder brothers who should be in the line of succession tend to marry foreign women and as first-born tend to be the children of their fathers' marriages to foreign women (or, in the case of Ishmael, of the servant chosen to remedy the reproductive failure of the wife taken from within the patriline). The classic struggle portrayed in Genesis and later chapters of the Old Testament is, then, between the claims of the younger brothers spurred on by the interests of their mothers, who are also of the patriline, versus the claims of primogeniture, which may pass the succession to the children of foreign women.

The Genesis example illustrates how the P graph leads to a fundamental change in the way we see kinship relations. In the absence of a means of visualizing a structure in its totality, as in a graph, kinship analysis tends to fall back on selective principles of illustration or explanation. Forsyth (1991), for example, has recently reviewed the kinship materials in Genesis in great depth, emphasizing the element of sibling rivalry between younger and older sons as marking a psychological and political transformation from a more strictly patriarchal system to a more egalitarian ethos that anticipates the themes of the New Testament. Not being able to visualize and analyze the network of kin relations in Genesis and the way in which the various roles (patriarch, lineage member, mother, wife, elder/younger son, etc.) fit together, he misses the crucial involvement of women as lineage members, as advocates of the younger sons, as descendents of the patriarchs, and as carriers of the family and cultural heritage in a priestly line. The P graph helps us to see that the cultural conflict is not just between elder and younger but involves marriage rules, insiders and outsiders, and the interlock of roles in the kinship network.

In contrast to the conventional genealogical approach, the P graph approach recognizes that, for the species to exist, some individuals must link the matings of their parents, of which they are offspring, with their own matings, by which they reproduce.[3] Whereas mating is a universal of reproducing societies, marriage is neither universal nor invariant, and the P graph approach accommodates variant kinship forms associated with producing offspring, such as single mothers and sociological parents. There may be a variety of culturally specific kinship idioms associated with a universal mating base. The computation of paternal and maternal parentage as single-valued functions is an aid in computation, but P graphs can easily convert to relational composition. The P graph is not restricted to abstract models but may be used to represent concrete individual cases. Algebras of kinship and social networks may be based on the analysis of concrete relations (White and Reitz 1983, 1984).

Rather than treating kinship "structures" as frozen in time, P graphs are compatible with longitudinal analysis of changes in kinship relations. The approach does not assume unity of the kinship group as do many more abstract kinship algebras (Tjon Sie Fat 1990:149) or require generational closure. In applying P graphs to concrete examples we may assume closure or not, as the case requires. Observed data may be considered as a partial sample of a larger social field which extends forward as well as back in time. The method may be used to compute any kind of kinship and marriage relations; it is only theories of "elementary" structures (Lévi-Strauss 1949) that stress marriage of blood kin. Structural theories of semicomplex and complex marriage systems might stress recurrent types of marriage circles or cycles, open-field cycles, etc. More individualistic or psychological theories might emphasize structures of extension and test for corroborating material entailments among relational kinship elements (White 1990).

The P graph approach facilitates the study of kinship and marriage systems in complex societies and may help

3. This embodies Malinowski's (1930:19) "flesh and blood" conception of kinship rather than the abstracted genealogies against which he railed.

to reinvigorate an evaluation of what has been learned ethnographically and theoretically (as in Lévi-Strauss 1949 or Héritier 1976, 1981) about kinship and marriage systems. It reconnects the approaches of two worlds—French and Anglo-Saxon—whose very different perspectives on the study of kinship have to date precluded consensus on theories and on the relation between theoretical models and empirical data.

Tufte (1983, 1990) and others have shown the importance of visualization in communication. The same is true in the development of scientific specialties. Klovdahl (1981) argues that network analysis and its concepts—centrality, reachability, role position, clique, flow, etc.—would not have developed as they did without graph theoretic images and measures. Conceptually, it is no small matter that kinship nets can be represented as graphs. Perhaps we are in a better position than before for a foundational reconceptualization in the analysis of kinship.

References Cited

DUQUENNE, VINCENT. 1991. *Program: General lattice analysis and design.* Paris: Ecole des Hautes Etudes en Sciences Sociales.

FORSYTH, DAN W. 1991. Sibling rivalry, aesthetic sensibility, and social structure in Genesis. *Ethos* 19:453–510.

FREEMAN, LINTON C., AND BRUCE MAC EVOY. 1987. *UCINET version 3.0 user's manual.* Irvine: School of Social Science, University of California, Irvine.

FREEMAN, LINTON C., AND DOUGLAS R. WHITE. 1992. Representation of social networks. MS.

FREEMAN, LINTON C., DOUGLAS R. WHITE, AND A. KIMBALL ROMNEY. Editors. 1989. *Research methods in social network analysis.* Fairfax, Va.: George Mason Press.

GUILBAUD, G. TH. 1970. Système parental et matrimonial au Nord Ambrym. *Journal de la Société des Océanistes* 26:9–32.

HÉRITIER, FRANÇOISE. 1976. "L'enquête généalogique et le traitement des données," in *Outiles d'enquête et d'analyse anthropologiques.* Edited by R. Creswell and M. Godelier, pp. 223–65. Paris: Maspero.

———. 1981. *L'exercice de la parenté.* Paris: Gallimard.

JORION, PAUL. 1982. Matrilateral cross-cousin marriage on microcomputers. MS, Department of Anthropology, Cambridge University, Cambridge, England.

———. 1984. L'inscription dans la structure de parenté: Ornicar? *Revue du Champ Freudean* 31:56–97.

JORION, PAUL, AND GISÈLE DE MEUR. 1980. La question Murngin, un artefact de la littérature anthropologique. *L'Homme* 20(2):39–70.

JORION, PAUL, GISÈLE DE MEUR, AND TRUDEKE VUYK. 1982. Le mariage Pende. *L'Homme* 22:53–72.

JORION, PAUL, AND E. LALLY. 1983. An algorithm for the analysis of genealogies as to prior kin connection between spouses. MS, Department of Anthropology, Cambridge University, Cambridge, England.

KLOVDAHL, ALDEN S. 1981. A note on images of networks. *Social Networks* 3:197–214.

LÉVI-STRAUSS, CLAUDE. 1949. *Les structures élémentaires de la parenté.* Paris: Presses Universitaires de France.

———. 1962. *La pensée sauvage.* Paris: Librarie Plon.

MALINOWSKI, BRONISLAW. 1930. Kinship. *Man* 30:19–29.

ROMNEY, A. KIMBALL. 1971. "Measuring endogamy," in *Explorations in mathematical anthropology.* Edited by P. Kay. Cambridge: M.I.T. Press.

TJON SIE FAT, FRANKLIN E. 1983. Age metrics and twisted cylinders: Predictions from a structural model. *American Ethnologist* 10:585–604.

———. 1990. *Representing kinship: Simple models of elementary structures.* Leiden: Faculty of Social Science, Leiden University.

TUFTE, EDWARD. 1983. *The visual display of quantitative information.* Cheshire, Conn.: Graphics Press.

———. 1990. *Envisioning information.* Cheshire, Conn.: Graphics Press.

WEIL, ANDRÉ. 1949. Sur l'étude algébrique de certains types de lois de mariage," in *Les structures élémentaires de la parenté,* by C. Lévi-Strauss, pp. 279–85. Paris: Presses Universitaires de France.

WHITE, DOUGLAS R. 1985. User's manual for statistical entailment analysis. MS, University of California, Irvine, Calif.

———. 1990. Ordering structures in kinship avoidances. MS.

WHITE, DOUGLAS R., AND VINCENT DUQUENNE. 1991. Lattice and entailment analysis of network structure. Paper presented at the 2eme Conférence Européenne sur l'Analyse des Réseaux Sociaux, Paris.

WHITE, DOUGLAS R., AND PAUL JORION. 1991. Marriage and kinship networks: Computation and application. MS.

WHITE, DOUGLAS R., AND KARL P. REITZ. 1983. Graph and semigroup homomorphisms on networks of relations. *Social Networks* 3:193–235.

———. 1984. REGGE: A regular graph equivalence algorithm for computing role distances prior to blockmodeling. MS, University of California, Irvine, Calif.

In the Eye of the Beholder: Mousterian and Natufian Burials in the Levant[1]

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The issue of intentional burial in the Middle Palaeolithic is a subject that has lately received much attention in the literature. In considering this question here, it is not our intention to suggest new or better criteria for identifying intentional burials. Rather, we attempt to demonstrate that application of the existing criteria is biased by preconceptions and differential treatment of biological and cultural variables.

The recent controversy regarding behavioural and biological changes in Upper Pleistocene hominids involves a number of distinct issues (summarized by Dibble and Chase 1990), of which the most important for our discussion is the problem of symbolic behaviour in Middle Palaeolithic hominids (Bar-Yosef 1989, Chase 1991, Chase and Dibble 1987, Lindly and Clark 1990) and especially the practice of burial (Binford 1968, Chase and

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