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ANTHROPOLOGY, MATHEMATICS, KINSHIP: A TRIBUTE TO THE ANTHROPOLOGIST PER HAGE AND HIS WORK WITH THE MATHEMATICIAN FRANK HARARY[1]

DAVID JENKINS
ROUNDHOUSE INSTITUTE FOR FIELD STUDIES
DVDJENKINS@HOTMAIL.COM

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Abstract: Over a long and productive career, Per Hage produced a diverse and influential body of work. He conceptualized and solved a range of anthropological problems, often with the aid of mathematical models from graph theory. In three books and many research articles, Hage, and his mathematician collaborator Frank Harary, developed innovative analyses of exchange relations, including marriage, ceremonial, and resource exchange. They advanced network models for the study of communication, language evolution, kinship and classification. And they demonstrated that graph theory provides an analytical framework that is both subtle enough to preserve culturally specific relations and abstract enough to allow for genuine cross-cultural comparison. With graph theory, two common analytical problems in anthropology can be avoided: the problem of hiding cultural phenomena with weak cross-cultural generalizations, and the problem of making misleading comparisons based on incomparable levels of abstraction. This paper provides an overview of Hage's work in an attempt to place it in the broader context of anthropology in the late-twentieth and early-twenty first centuries.

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Over a long and productive career, Per Hage produced a diverse and influential body of work. He conceptualized and solved a range of anthropological problems, often with the aid of mathematical models from graph theory. In three books and many research articles, Hage, and his mathematician collaborator Frank Harary, developed innovative analyses of Oceanic exchange relations, including marriage, ceremonial, and resource exchange. They advanced network models for the study of communication, language evolution, kinship and classification. And they demonstrated that graph theory provides an analytical framework that is both subtle enough to preserve culturally specific relations and abstract enough to allow for genuine cross-cultural comparison. With graph theory, two common analytical problems in anthropology can be avoided: the problem of hiding cultural phenomena with weak cross-cultural generalizations, and the problem of making misleading comparisons based on incomparable levels of abstraction.

Per Hage died in June of 2004 after a long struggle with leukemia. He was sixty nine years old and engaged in a provocative study of kinship terminologies in the world's major language families, a study that brought him great pleasure and yielded a variety of new insights into the structure and evolution of kin terms. Frank Harary died a few months later, at eighty three years old, after a lifetime of prodigious mathematical output.[1]

I intend to describe Hage's work and the mathematics he and Harary used in their diverse analyses, but I won't describe in any detail the mathematics itself. That task would be much too lengthy. The mathematical definitions, though reasonably straightforward, require careful description and example, which are readily accessible in Hage and Harary's publications. Let me simply note informally that a *graph* is a mathematical structure consisting of a finite set of nodes, some pairs of which are joined by edges. A research problem involving structure is first modeled as a graph, often presented in pictorial form, then solved by the application of the concepts, theorems, and algorithms from graph theory. By my count, Hage and Harary employed seventeen theorems in their first book, eighteen theorems in their second book, and eleven theorems and six algorithms in their third book. As they note in Exchange in Oceania: "We wish to emphasize right at the outset that the ultimate value of graph theory for anthropology will depend not just on the use of its pictorial representations, but also on the application of its theorems" (p. 2). They go on to suggest that "By specifying properties of graphs that necessarily follow from given conditions, theorems enable one to draw conclusions about certain properties of a structure from knowledge about other properties. Thus the answer to many research questions depends not on the accumulation of more data but on the examination of the structural properties of graphs" (p.9).

In what follows I will sometimes refer to Hage as the author of the work under review, and sometimes to Hage and Harary. My understanding is that although for more than twenty

years these two scholars collaborated on their joint venture applying mathematical models to anthropological data, Hage typically drafted the article or chapter or book, and Harary clarified and extended the mathematical treatment.

STRUCTURAL MODELS

In 1983 Hage and Harary published their first book, Structural Models in Anthropology (Cambridge University Press). It introduced a basic set of graph theoretic concepts, definitions and theorems for the analysis of diverse cognitive, social and cultural forms. An expanding field of mathematics, graph theory has significant applications in a wide range of disciplines, including computer science, operations research, chemistry, physics, economics, biology, architecture, and geography. As Structural Models shows, anthropology belongs with this range of disciplines and, like them, clearly benefits from the explicit adoption of mathematical models into its theoretical armamentarium.

In his forward to the book, J. A. Barnes noted that Hage and Harary gave social scientists renewed hope in the structuralist enterprise. They convincingly demonstrated that graph theory applied to ethnographic evidence produced "results that could not have been obtained with unassisted common sense, results that add significantly to our understanding of the social and cultural processes taking place in the real world." Barnes argued that the book represented a shift from rough carpentry to cabinet-making. It provided anthropologists with a shared technical vocabulary that cleared away much of the confusion about "structure" in the social sciences. "Here in this new book," Barnes said, "we have at last a comprehensive range of examples from graph theory being applied to data from the real world with the elegance and precision we rightly expect from pure mathematics."

Hage and Harary intended Structural Models as a concrete demonstration of the usefulness of graph theory for the analysis of diverse human phenomena. Its topics are varied and include Puluwatese navigation techniques and mnemonics; drift voyaging in Polynesia; Orokaiva gift exchange; Mayan ceremonial architecture; Melanesian social structure; New Guinea Big Man leadership systems; kinship, alliance and status structures in various places such as New Guinea, Tikopia, Tonga, Truk, the Solomon Islands, the Western Carolines, India, Mexico, and the Kalahari; social group fission in a work group in Zambia; Shoshone piñon nut gathering strategies; Chinese Five Element Theory and the structure of the *I Ching;* Arapesh culinary symbolism; and Micronesian techniques for predicting the weather based on how crabs dig holes in the sand.

In the middle of the discussion of such diverse topics is the gem of the book: a clear and convincing demonstration of the underlying structure of Freud's Oedipus myth. Starting with Lévi-Strauss's observation that Freud's versions could be interpreted as transformations of the Greek myth,[2] Hage and Harary show that logical concepts from graph theory—specifically notions of *structural duality*—could advance myth analysis in new ways. Hage chose Freud as an irresistible topic for discussion: A Viennese autochthonous hero, in his phrase (1979). With Freud as the topic, Hage and Harary proceed to sort out the logical possibilities of the notoriously problematic notion of "opposition" in anthropological analyses of symbolic systems.

The point for Hage was not simply a catalogue of interesting cultural bits and pieces from different places. The point was to show how these, and by implication many other, cultural phenomena could be analyzed with graph theoretic concepts and theorems. As Hage often

pointed out, graph theoretic concepts are already in anthropological discourse, although in disguised or awkward form. At the beginning of Structural Models in Anthropology he says:

> Anthropology is fundamentally the study of sets of social and cultural relations whose diversity and pervasiveness is illustrated by such terms as "exchange," "hierarchy," "classification," "order," "opposition," "mediation," "inversion," and "transformation." (p.1)

Hage goes on to say that the analysis of these kinds of relations presupposes some sort of model, usually and often inadequately described in everyday language. "The question thus arises," he notes, "as to whether, in many contexts, mathematical formulations might not be helpful; and if so, what kind of mathematics."

Structural Models in Anthropology is an extended answer to this question. Hage and Harary use *graphs, trees, blocks, signed graphs, directed graphs, networks, groups, matrices*, and the concepts of *structural duality* and *centrality* in their analyses of the above mentioned topics. Along the way they employ seventeen theorems whose usefulness in anthropological analyses remain underdeveloped.

Hage did not expect the wholesale adoption of mathematical models into anthropology. Social and cultural worlds are messy and contingent and humans exhibit an impressive range of inventiveness and unpredictability. Ethnographic description of such worlds is itself fraught with difficulty, as is adequate interpretation. Still, it is not the case that anything goes, that patterns are absent from human behavior, and that all anthropologists can or should do is describe and interpret the fragments of another's cultural world they are privileged to witness. If the focus remains not within a culture but across all cultures, the question remains whether specific patterns of human behavior—for example in social organization, or kinship, or cognition, or linguistic categories—can be found in all cultures; the associated question is whether there is an abstract analytical language that suffices for the analysis of these patterns.

Graph theory, as exemplified by the publication of Structural Models, provides one such language of analysis and comparison. Throughout this book, Hage and Harary demonstrate that social scientists need not shy away from the rapidly developing and increasingly sophisticated family of graph theoretic models—models that are especially well-suited for the analysis of diverse human phenomena, that may provide one of the better means for adequate cultural comparison, and that have been used to such great advantage in other disciplines. The search for comparative tools for analyzing human behavior may never end, but at least in graph theory we have a useful starting point.[3]

"The legitimacy of the comparative method," Lévi-Strauss (1985) emphasized in The View from Afar, "does not rest on massive and superficial resemblances." To the contrary, "Analysis has to take place on a level deep enough to allow us to discern, at the base of all social life, the simple features that combine into rudimentary systems, which may eventually become the stuff of more complex and more completely integrated systems with entirely new characteristics." Comparative analysis was Per Hage's great skill. He could see the underlying patterns that emerged in diverse cultures, and developed the technical ability to analyze them.

EXCHANGE

Between the 1983 publication of Structural Models in Anthropology and the 1991 publication of Exchange in Oceania: A Graph-theoretic Analysis (Oxford University Press),[4] Hage published a number of papers, notably a *boolean group* analysis of Arapesh sexual symbolism (with Harary, 1983b), which analyzed the intricate relations involved with Arapesh notions of the body and its substances; and a *Markov chain* analysis of the *kula* ring (with Harary and Brent James, 1986), which simulated the flow of armshells and necklaces around this famous network in order to study the distribution of these valuables and analyze the relationship between network position and social organization. But his primary concentration during this time was on exchange relations throughout Oceania and on the development of graph theoretic models for their analysis.

Exchange in Oceania focused on Polynesian, Micronesian, and Melanesian societies. It developed a graph theoretic analysis of the great range and variety of the exchange systems found in those societies. "Our intention," Hage writes,

> is not to give an encyclopaedic account or even a detailed survey of exchange forms in Oceania, but rather to demonstrate, with reference to diverse empirical cases, how graph theoretic models can contribute to the innovative as well as the rigorous analysis of these forms. While agreeing completely that the role of the structural anthropologist is only to discover and study the 'structured or structurable islands' that bathe in an 'ocean of contingency' (Lévi-Strauss in Bucher 1985), we none the less wish to indicate that the islands are more numerous and varied than commonly imagined, that the ocean resembles the Pacific more than it does the Atlantic. (p. 1-2)

Prior anthropological studies of exchange in this region are devoted to a number of topics, among them kinship and marriage relations, communication and exchange networks, social organization, gender relations, ritual forms, and beliefs about bodily pollution. Hage and Harary set out to provide a model of exchange relations in general, a model that would describe and analyze such relations. They also wished to demonstrate that radically different ethnographic forms can have the same or similar logical structure.

As with their earlier book, a number of research problems are conceptualized and solved. For example, Hage and Harary provide a graph theoretic definition of dual organization, a widespread and probably archaic type of Melanesian social structure which exhibits a variety of empirically different forms. All of these forms can be characterized as a *bipartite graph*, that is, a graph whose node set V can be partitioned into two subsets V_1 and V_2 such that every edge of G joins (a node of) $V_1$with (one in) V_2 (p. 39). With this basic definition, it becomes clear that the empirically distinct forms of social organization among the Arapesh, Tanga, and Etoro are all bipartite, that is, they are all dual forms, even if these forms are implicit or hidden. Once the underlying bipartite organization is apparent, other more complex characteristics can be studied, such as the cyclical and relational properties of marriage, descent and ceremonial transactions.

In addition to analyses of marriage and ritual exchange, Hage and Harary develop graph theoretic models of overseas trade networks, with a focus on reconstructing and studying the traditional exchange network that connected the islands in Western Micronesia. They show that

locational advantage in such networks is often more significant than either demographic or environmental factors in the development of social stratification or trading success. And they demonstrate the analytical usefulness of precisely defining different types of central location, in order to study economic potential and success, emerging political hierarchies, and dominance between trading partners.[5]

They also extend their Markov chain analysis of the *kula* ring, which simulates the flow of valuables around a group of 20 islands off the eastern coast of New Guinea, an exchange network initially described by Malinowski. Hage and Harary's simulation of the flow of armshells and necklaces highlights a number of important aspects of the exchange network, such as the location of central and marginal islands, the uneven distribution of valuables around the *kula* ring, and the reasons for the development of political hierarchy on some islands but not on others. Their model additionally provides the occasion for informed speculation about the initial development of *kula* exchange.

One important emphasis in this book is on enumerating all logically possible forms of an exchange relation. As an example, Hage and Harary provide a mathematical generalization of Lévi-Strauss's "atom of kinship." For Lévi-Strauss, the atom of kinship is characterized by the group consisting of a husband, wife, offspring, and the representative of the social group which gave the woman to the man, for example (the simplest case) the wife's brother. There are six relations in the atom of kinship, four of which Lévi-Strauss analyzes: brother-sister, husband-wife, father-son, and mother's brother-sister's son. Hage and Harary's generalization shows that there are eight logically distinct sets of relations possible. Enumerating all eight "is not an idle exercise," they insist, "for it directs attention to those empirical structures which have already been studied by anthropologists, and those which remain to be studied" (p. 193).

Finally, they describe the interactions between binary operations on graphs and mathematical groups. To this end, Hage and Harary analyze pollution beliefs in Highland New Guinea. In particular they show that pollution beliefs in Mount Hagen can be analyzed as a *transformation group*, in which the entire system of beliefs is the object of study. They show that beliefs concerning menstrual pollution are logically related to beliefs about cooking, poison, and semen—all expressed in the idiom of marriage. The general point is to show that a particular belief should not be isolated from others, but studied as a set. In this way, the internal logic of a seemingly disparate set of beliefs is revealed. Additionally, the model of a transformation group, as Hage and Harary note, "permits the comparison of related belief systems, not term for term, but on the basis of an underlying system of relations, which is also the level to seek valid correlations between symbolic and social systems" (p. 239). The approach is thus both mathematical and Durkheimian, clarifying the logic of cultural symbols that define and bound a set of relations, and demonstrating how certain of these symbols correspond to social organization.

NETWORKS

After the 1991 publication of Exchange in Oceania, Hage published a number of papers on diverse topics, including an important clarification of the concept of hierarchical opposition (with Harary and Milicic, 1995); two papers on minimum spanning trees (with Harary, 1995; and with Harary and James, 1996); and an unexpected and delightful analysis of tattooing, gender,

and social stratification in Polynesia (with Harary and Milicic, 1996). Much of his effort during this time, however, was on network analysis.

Island Networks: Communication, Kinship, and Classification Structures in Oceania (Cambridge University Press) was published in 1996, with a dedication to Claude Lévi-Strauss. In the preface Hage and Harary refer to their earlier book, Structural Models in Anthropology, in this way: "Much of the inspiration for that book, as for all of our research, came from Claude Lévi-Strauss's (1949, 1962) theories, which focus on the logical, combinatorial, and isomorphic properties of kinship and classifications systems, prefiguring the application of finite mathematics to anthropology."

Island Networks is explicit in its mathematical applications, perhaps for some readers too much so. But for those with the patience to work through the mathematical notation and absorb the rationale behind the use of graph theory for the analysis of various network problems, the results are compelling.

Beginning with a theorem defining the properties of *trees*,[6] the simplest of all graphs and network models, Hage and Harary analyze as *rooted trees* the Yapese prestige-good system, which, based on three different types of gift relations, connected fourteen islands across 1,200 kilometers of ocean. They analyze as *twin binary trees* various classification systems organized by what anthropologists have called

- "recursive dualism" (Admirality Islanders in Melanesia; Eyde, 1983)
- "perpetual dichotomy" (Lauan society in eastern Fiji; Hocart, 1929, 1952)
- "recursive complementarity" (eastern Indonesian cultures; J. J. Fox, 1989),
- "reciprocal logic" (Moalan society in Fiji; Sahlins 1976)
- "relational contrast" (Balinese; Boon 1990), and
- "hierarchical opposition" (India; Dumont 1980)

but which in fact have the same underlying structure—a structure that is revealed once these diverse systems are analyzed graph theoretically. They analyze as *in trees* cognatic landholding descent groups among the Tuamotu atolls in East Polynesia. And they use the *cycle rank* of a graph to measure the network connectedness of exchange relations in West Polynesia and Melanesia.

A discussion of *minimum spanning trees* provides the opportunity to introduce three algorithms, which are then used to 1) analyze linguistic subgroups in the Tuamotu Islands in Polynesia, and to show how and why dialect groups are partitioned, 2) suggest the pattern of the evolution of chiefdoms in the one hundred or so islands in the Lau archipelago of eastern Fiji, and 3) improve a standard method of "close proximity analysis" in archeology, developed to analyze clusters of cultural similarity, by showing how computation can be made more efficient, with the example of Lapita cultural spread throughout Oceania.

One major contribution of Island Networks is the elucidation of the structure of the conical clan—a type of social organization that has been independently discovered, by Service's count (1985), five times, to which Hage and Harary add two more. The model they use is called a Depth First Search Tree (DFST), familiar in computer science, and they show that the unique ranking of individuals in this type of social organization can be modeled in a way that "gives an exact, general, and intuitively appealing characterization of the conical clan in all of its forms"

(p. 91). Tongan, Marshallese, and Kachin variants, where rank is defined either by primogeniture or ultimogeniture, are shown to exhibit similar structures.[7]

Reading Per Hage's account of the conical clan is a lesson in the intellectual history of anthropology. One of Hage's explicit aims was to incorporate into his analysis the important but frequently overlooked contributions of prior scholars. In the clarification of the structure of the conical clan, we find references to familiar names such as Raymond Firth, E.E. Evans-Pritchard, Edmund Leach, Marshall Sahlins, George Peter Murdock, and Leslie White; but there are also scholars whose contributions are central but less well known: Paul Kirchhoff, Edward Winslow Gifford, Wilhelm Milke, Leonard Mason. The conical clan was first described in 1864, but despite considerable effort to clarify its structure, it wasn't until Hage and Harary's *search tree* analysis that its form was finally clarified.

Hage and Harary extend the discussion of search trees to develop, with evidence from historical linguistics, an analysis of Proto-Oceanic kinship systems, with a focus on descent, alliance and kin terminology. They additionally used *digraphs*, which are graphs with arrows on their edges indicating relational direction, to clarify and improve existing evolutionary models of kinship organization, and *semilattices*, models that capture unilinear and multilinear, as well as diverging and converging, paths. This led to a second major contribution in Island Networks: a model of the evolution of Oceanic sibling terms and social organization, based on Nerlove and Romney's (1967) study of the logically possible types of sibling terminologies, Murdock's (1968) comparative study of kin terms, and Greenberg's (1966, 1990 [1980]) study of language universals, together with the provocative work of specialists in Oceania.

As with his discussion of the conical clan, Hage explicitly recognized earlier contributions to kinship research. He cites Murdock's (1968) somewhat fanciful history of kinship studies, which begins with the Founder (Lewis Henry Morgan), followed by the Early Giants (Kroeber, Rivers, Radcliffe-Brown, Lowie), then the Later Masters (Firth, Fortes, Eggan, and Lévi-Strauss), and finally on to the Modern Innovators (Goodenough, Lounsbury, Romney and D'Andrade, among others). In a footnote, Hage suggests that "the fourth stage is also the beginning of a decline in which [quoting Murdock] 'certain self-styled "social anthropologists" today no longer report kinship terms in their monographs or do so half-heartedly or incompletely—a tendency that would have profoundly shocked the Early Giants and the Later Masters.'" Hage goes on to comment: "One wonders how Murdock would have characterized the present period, when either the reality or the variety of kinship systems is denied—The Late Dwarfs, perhaps?"[8]

Hage had high hopes for Island Networks, his most sophisticated and innovative work. In the preface, he states that "The applications in this book are highly varied, and the interested reader will no doubt discover analogues to every research problem we present." A paragraph later, he suggests that "There is a parallel here with the second author's book, Graph Theory, published in 1969, which became in 1978-9 the fifth most cited reference in the research literature of mathematics. Virtually every section of every chapter of that book has become a special field of research and is now the subject of a separate book."

The interested reader of Island Networks, as well as Hage and Harary's earlier work, will no doubt discover analogues to each of the research problems they conceptualized and solved. The techniques they advanced, and the new lines of research they opened up, provide points of departure for novel research in a surprising range of topics, only some of which I have described.

In the conclusion of the unedited manuscript of Island Networks, after listing all of the analytical advantages of network models in anthropology, Hage wrote as his final sentence, "Let the punishment fit the crime." He later removed this phrase, not wishing to sound flip at the completion of such a work. A few years later Per told me that as he and Frank worked through the final chapter together, Frank—a diminutive, quirky, and highly accomplished mathematician—danced around the room, singing from Gilbert and Sullivan's "Mikado": "My object all sublime, I shall achieve in time—To let the punishment fit the crime—The punishment fit the crime…" Frank Harary's dance was an expression of the joy and satisfaction they both felt at the completion of their third book, the emotional equivalent of the mathematician's Q.E.D.

Never one to remain idle, Hage next turned his full attention to kinship, one of the venerable topics in anthropology. His goal was to develop a world-historical analysis of the evolution of kinship systems.

KINSHIP TERMINOLOGY

After the publication of Island Networks, the pace of Hage's work accelerated. He was delighted to have come across Joseph Greenberg's 1966 study "Language Universals," and realized that Greenberg's remarkable analysis, neglected in cultural anthropology,[9] could be extended into a research program on the evolution of kin terminologies in all of the world's seventeen major language families (Ruhlen 1987).

Hage received two National Science Foundation grants to support his new research interest. "Kinship terminologies," he wrote in his grant proposal, "are anthropology's treasure." Hage emphasized that of the various systems of classification anthropologists have gathered, kinship classifications are the most complete. About no other system of classification do we have such rich data. These data, moreover, have implications for understanding aspects of language, cognition, social organization, and historical change. Hage proposed an analysis of the evolution of kin terms in the world's major language families, based on clear preliminary evidence that kin terms evolve in predictable, albeit uneven, ways. Given the patterned changes in kin terms over time, it is possible to develop analyses of prehistoric kin terms, and from them to make plausible reconstructions of prehistoric kinship systems. Coupled to archaeological and genetic evidence, reconstructed proto-kinship systems provide additional evidence about social organization, migration patterns, and language stability and change. One NSF reviewer thought that Hage's study would produce results as significant as Lévi-Strauss's Elementary Structures of Kinship. Another reviewer, in a response that mystified Hage, claimed to find nothing of value in the proposal, and indeed could understand nothing about it.[10]

Hage published his results at a steady rate, working on his own and with several collaborators, among them the mathematician Frank Harary, the cultural anthropologist Bojka Milicic, and the linguists Mauricio Mixco and Jeff Marck. His enthusiasm for research on kin terminologies was boundless, despite his illness. He worked with great pleasure mixed with a sense of urgency. He was, as he told me, very happy to start work each day and regretted having to stop at day's end. Over this time he published twenty journal articles and two book chapters, from "Unthinkable Categories and the Fundamental Laws to Kinship" (1997), to "Marking Universals and the Structure and Evolution of Kinship Terminologies: Evidence from Salish" (1999a), to "Matrilineality and the Melanesian Origin of Polynesian Y Chromosomes" (2003, with Marck), to the posthumous "Dravidian Kinship Systems in Africa" (2006). His publications

include work on Maya, Bantu, Polynesian, Salish, Proto-Micronesian, Proto-Polynesian, and Proto-Nostratic systems, and he conducted considerable research on kin terms in many other language families. He anticipated eventually publishing his research in book form.

"Unthinkable Categories" addresses an aspect of Françoise Héritier's (1981) general theory of kinship systems. In her seminal work, L'Exercice de la parenté, Héritier analyzes two "unthinkable" kinship categories implied in Lowie's (1928) and Murdock's (1949) typologies, which, though logically possible, are not empirically realized. Lowie argues that there are four types of male kinship terminologies in the first ascending generation:

1. Generational, where one term suffices for father, father's brother, and mother's brother: F = FB = MB.
2. Lineal, which has two terms, one for father and another for father's brother and mother's brother: F ≠ FB = MB.
3. Bifurcate merging, which has two terms, one for both father and father's brother, and another for mother's brother: F = FB ≠ MB.
4. Bifurcate collateral, which has three terms, one for father, one for father's brother, and one for mother's brother: F ≠ FB ≠ MB.

Lowie did not consider the fifth logically possible type, perhaps because it doesn't occur.

5. F = MB ≠ FB.

Héritier accounts for the non-occurrence of this fifth type with her first law of kinship, which, she argues, has far-reaching social implications: "cross-solidarity is never stronger than parallel solidarity and a cross-relation between individuals or groups is never the implicit basis of equivalence or identity" (1981:38). She further argues that it is "unthinkable that the relation between two men linked through a woman, sister of one, wife of the other, could be closer than the relation between two brothers" (1981:42). Hence the kinship equation F = MB ≠ FB does not occur.

Héritier similarly considers four types of cousin terminologies, simplifying Murdock's (1949, 1970) typology.[11]

1. Parallel cousins = cross-cousins= siblings (Hawaiian).
2. Parallel cousins ≠ cross-cousins ≠ siblings (Sudanese).
3. Parallel cousins = cross-cousins ≠ siblings (Eskimo).
4. Parallel cousins = siblings ≠ cross-cousins (Iroquois, Crow, Omaha).

A fifth type, logically possible but not found, has one term for siblings and cross-cousins, and a second term for parallel cousins. Héritier accounts for the non-occurrence of this fifth type with her first law of kinship identity and difference.

5. Siblings = cross-cousins ≠ parallel cousins.

As Hage points out, Greenberg explains the non-occurrence of the empirically unrealized kinship categories not in sociological terms but in cognitive-linguistic terms. His theory provides the means to predict the overall structure of kinship terminologies, whose analyses become more complicated when multiple characteristics are defining features—such as an elder/younger distinction, a male/female distinction, a cross/parallel distinction, and a sex of speaker/sex of referent distinction—and when distant relatives, descent relations, and alliance structures are taken into account. Additionally, Greenberg's theory allows one to analyze evolutionary changes to the structure of kinship terminologies, based on the successive addition or deletion of contrasting characteristics. By comparison, Héritier's theory allows for neither prediction of unrealized categories nor evolutionary analysis.[12]

Greenberg proposes two major determinants of kinship terminologies: the avoidance of disjunctive categories, and the effects of marking.

Disjunctive categories are defined by different combinations of attributes, rather than the joint presence of attributes. For example, in analyzing kin terms for female relatives in the first ascending generation, Greenberg (1990 [1980]: 320) makes the following observations:

> The principle involved is the avoidance of disjunctive definitions. There is no way of demarcating by a single set of defining properties a term which embraces the mother and the [father's] sister without including in its reference the [mother's] sister. This is because mother's sister shares matrilineality with mother and collaterality with father's sister, but there is no common property of mother and father's sister, the two most different terms, except female, first ascending generation, and this includes mother's sister in its reference.

Graphically, a disjunctive kinship category is one that cannot be represented by a single endnode of a twin binary tree, while a conjunctive category can be. Figure 1 shows five twin binary trees representing first ascending male kinship terminologies; the fifth is disjunctive. In these graphs, A, B, and C stand for kin categories. The dimensions of contrast are lineal vs. collateral, and cross vs. parallel. Number 5, the unthinkable terminology, is one in which a single term refers to father and mother's brother, and another term refers to father's brother. It is disjunctive because term A (F, MB) is defined by incompatible combinations of attributes, that is, by both cross and parallel characteristics.

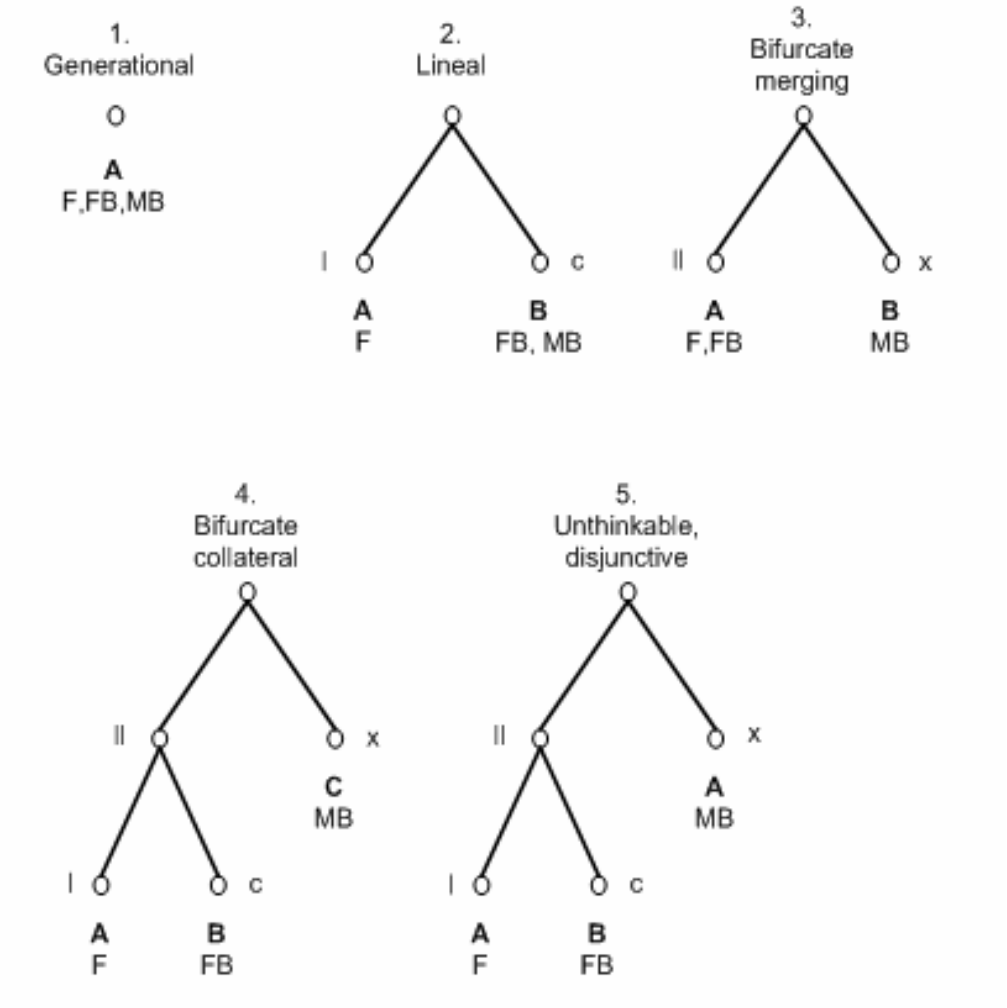

FIGURE 1: CONJUNCTIVE AND DISJUNCTIVE FIRST ASCENDING GENERATION KINSHIP TERMINOLGIES, AFTER HAGE 1997

Hage shows, following Greenberg, that the absence of logically possible kin categories can be explained, initially, as an instance of a universal tendency to avoid disjunctive categories. This is true for cousin terminologies, grandparent terminologies, sibling terminologies, and for other categorical systems in general. For grandparent terminologies, Greenberg demonstrated that of the fifteen logically possible types, seven are disjunctive. Combining his sample of 100 kinship terminologies with Murdock's sample of 566 terminologies, Greenberg then discovered that the disjunctive types are very rare, occurring in as few as three societies.

Nerlove and Romney's (1967) analysis of sibling classification produced similar results. They found only four sibling terminologies with disjunctive categories in a sample of 240 terminologies. In their study, Nerlove and Romney point out that the number of logically possible sibling terms is 4,140, based on three dimensions of contrast—a cross/parallel distinction, an elder/younger distinction, and a male/female distinction. These three contrasts produce eight sibling kin types:

1. Cross, Elder, Brother.
2. Parallel, Elder, Brother.
3. Cross, Elder, Sister.
4. Parallel, Elder, Sister.
5. Cross, Younger, Brother.
6. Parallel, Younger, Brother
7. Cross, Younger, Sister.
8. Parallel, Younger, Sister.

One sibling term subsumes all of the contrasts; two sibling terms partition these eight kin types in 27 ways; three sibling terms partition them in 966 ways; on through a logically possible 4,140 partitions. The majority of the logically possible terms are disjunctive; 146 are conjunctive. In addition to confirming the rarity of empirically occurring disjunctive sibling categories, Nerlove and Romney further predict that of the 146 conjunctive sibling categories only twelve types will actually occur with any frequency—a prediction subsequently confirmed, in large part, in Murdock's (1968) sample of 800 societies (Hage 1997).

In their combinatorial analysis of sibling terms, Nerlove and Romney reduce the logically possible conjunctive terms to twelve ideal types, based on one of Greenberg's marking hypotheses. Marking, or markedness, refers to a hierarchical relationship between values within the same level of contrast, in which the unmarked term of an opposition is more general and simpler than the marked term. In addition, the presence of a marked term implies the presence of the unmarked term, but not necessarily conversely. Trubetzkoy (1929, 1975) discovered marking effects in phonology, which Jakobson (1971 [1932]) subsequently generalized to grammar. Greenberg then applied marking to kinship terminologies, as part of his demonstration that marking effects are found at every level of language, phonological, grammatical, and lexical.

Greenberg proposed ten criteria of markedness, five of which are applicable to kinship terminologies (Hage 1999a; 2001):

1. *Universal implicational statement*. The presence of the marked term implies the presence of the unmarked term, but not necessarily the converse. For example, the presence of cross distinctions in cousin terms implies the presence of cross distinctions in uncle terms (D'Andrade 1971).
2. *Zero expression in the unmarked term*. The marked term is overtly indicated. For example, in English kin terminology the unmarked term *parent* is not overtly indicated, while the marked term *grandparent* is. Similarly in English, the consanguineal relation "father" is unmarked, whereas the affinal relation "father-in-law" is marked. In Chinese kin terms, affixes indicate marked terms and distinguish affinal vs. consanguineal, collateral vs. lineal, and nonpatrilineal vs. patrilineal relations (Lin 1986).
3. *Par excellence expression*. The unmarked term may represent the opposite of the marked term, the entire category, or both. For example, in Fijian the term for 'younger parallel sibling' also means 'sibling' generally, regardless of sex or age (Hage 2001).
4. *Syncretization*. When categories intersect, the distinctions in the unmarked

category are absent or neutralized in the marked category. This criterion Nerlove and Romney (1967) used in their sibling terminology analysis. For example, sex distinctions in English are present in sibling terms but are absent or neutralized in cousin terms. In Malay, sibling distinctions for sex and relative age are neutralized in cousin terms. Thus the terms for 'older brother' (*abang*), 'older sister' (*kakak*), and 'younger sibling of either sex' (*adik*), "are all obliterated in the single [cousin] term *sa-pupu*" (Greenberg 1966:75).

5. *Defectivation*. Certain categories in the unmarked term are absent in the marked term. In English there are terms for 'brother-in-law' and 'sister-in-law' but not for 'cousin-in-law.'

Based on a large database of kin terms from a variety of languages, Greenberg (1990 [1980]:318) additionally suggests that "lineal is unmarked as against collateral, consanguineal is unmarked as against affinal, male is unmarked as against female in regard to sex of referent, older is unmarked in relation to younger." He goes on to note that "In general, the closer a generation is to ego, the more unmarked it is."

Each of these marking statements Greenberg intended as a hypothesis, to be tested against contemporary kinship terminologies and against reconstructions of proto-kinship terminologies. For some categories, it may be impossible to find universal marking relations. Citing Lounsbury's (1968 [1964]) study of Iroquois, Greenberg (1966) notes, for instance, that "it may well be that neither male nor female can be described as the unmarked category on a universal basis," a prediction confirmed in Hage and Harary (1996). Nevertheless, the "master principle" of marked and unmarked categories provides an approach to analyzing kin terms analogous to analyzing marked and unmarked relations in phonology and grammar. The approach is deductive and comprehensive and "leads to a general understanding of kinship terminologies as hierarchically ordered systems" (Hage 1999a:424).

In his various papers on the evolution of kin terms, Hage demonstrates that Greenberg's theory can be interpreted diachronically and used to infer characteristics of prehistoric kinship systems. The universal implicational statement suggests that as kin terminologies change marked terms are added last or lost first. The method to test this idea is straightforward. It consists of comparing cognate kin terms from different languages within the same language family—a method familiar in historical linguistics—and then inferring, based on marking effects, the direction of terminological change. I will provide two brief examples.

Figure 2 shows a semilattice model of the evolution of Salish terms for parents' siblings.[13] This model is based on Elmendorf's (1961) study of kinship terminologies for uncles, aunts, nephews, nieces, grandparents and grandchildren in fourteen Salish languages, spoken in the Pacific Northwest of North America. Cognate terms for parents' siblings are shown; blank spaces indicate terms unique to particular languages. Elmendorf argued that proto-Salish terminology was similar to Spokane, which had the most complex system, and is shown here as representative of the original system. The evolutionary trend is toward simplification. The first distinction to disappear is sex of speaker, represented in the model as man speaking (m.s.) and women speaking (w.s.). Next the distinction in aunt or both aunt and uncle terms disappears. Finally, sexual distinctions are lost, leaving a single term for all parents' siblings.

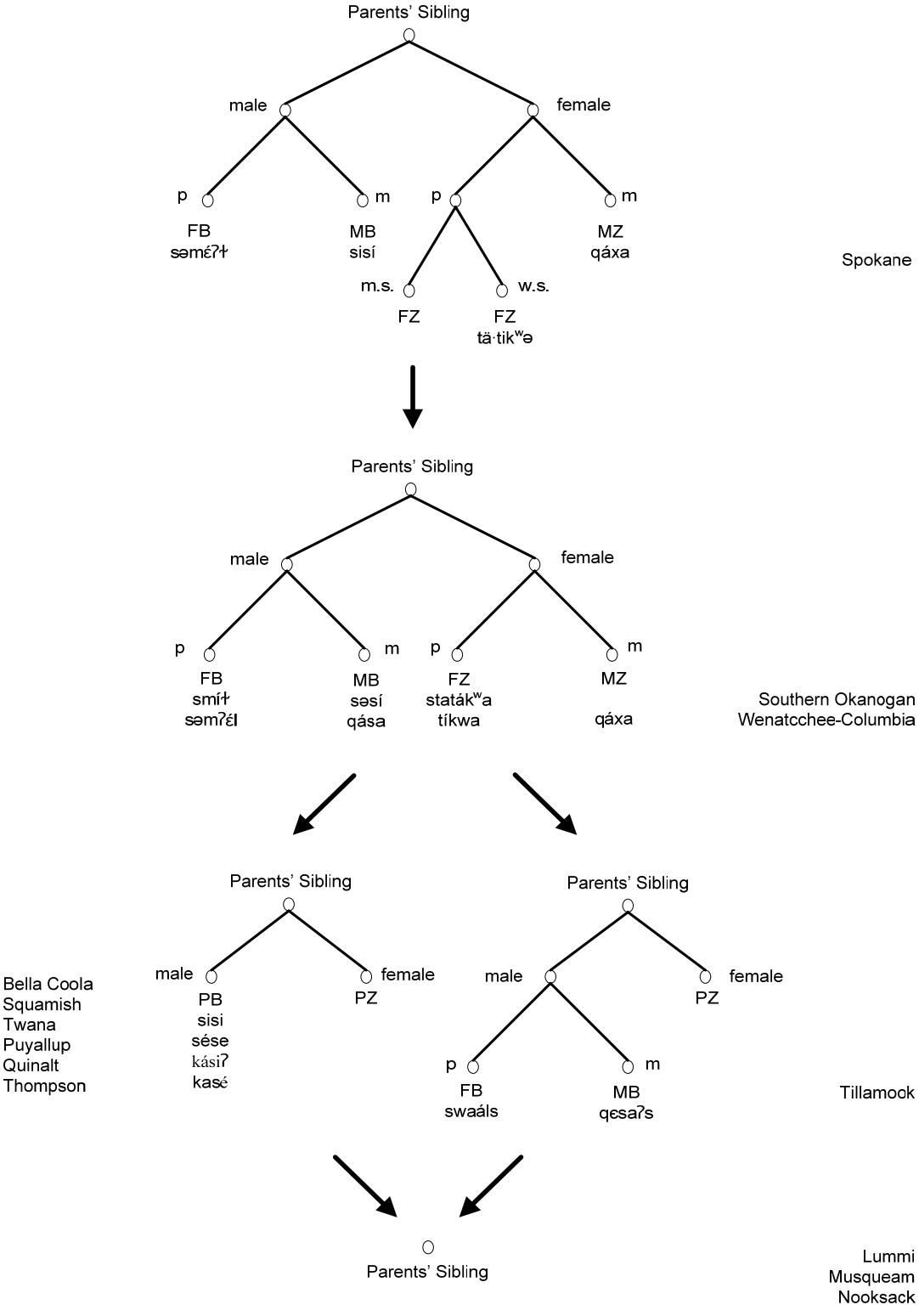

FIGURE 2: EVOLUTION OF SALISH PARENT'S SIBLING TERMINOLOGIES, AFTER HAGE 1999

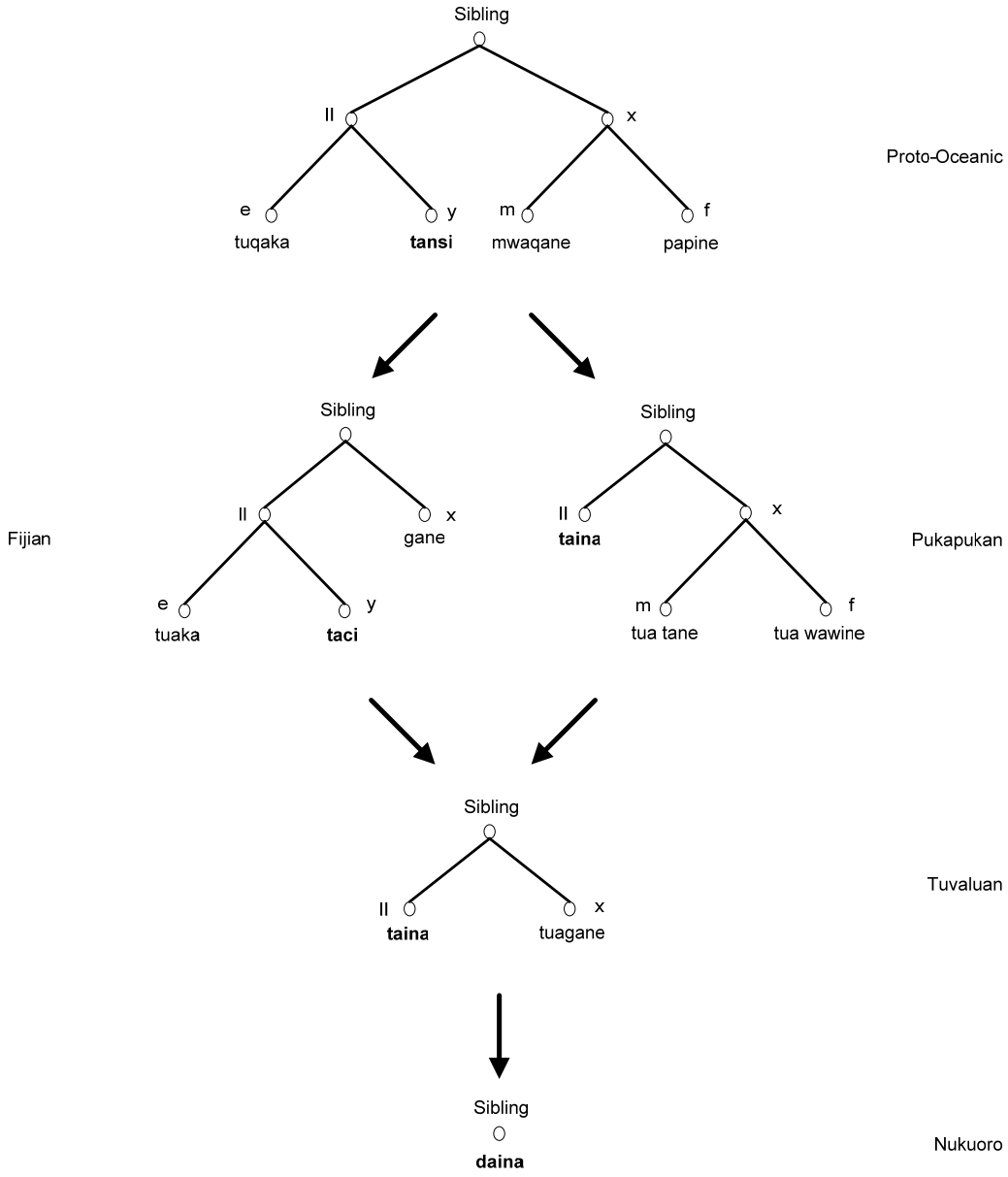

FIGURE 3: EVOLUTION OF OCEANIC SIBLING TERMINOLOGIES, AFTER HAGE 2001

Hage analyzes marking effects on Salish terminologies for siblings, first ascending generation male consanguines, grandparents, and parents' siblings. In this way the structure of Salish kin terms across fourteen languages becomes evident; the mechanism of change based on marking effects becomes evident as well. When combined with analyses of other language families, it is increasingly clear that kin terms evolve in a predictable direction, with various of the marked categories becoming lost first.

The second example concerns the evolution of Proto-Oceanic sibling terms. Among kinship systems, the senority, or relative age, distinction, when present, is not consistently marked. In

Proto-Oceanic society, with a probable rule of primogeniture, the term for elder sibling was marked, indicating the position of heir among siblings and also relative rank (Hage 1999b). If the term for elder sibling was marked, then, predictably, it should be lost before any unmarked term for younger sibling. This pattern obtains among the related languages Pukapukan, Fijian, Tuvaluan, and Nukuoro, as shown in the semilattice model in Figure 3. Remarking on this model Hage notes, "In the evolution of Oceanic sibling terminologies, when the seniority distinction is neutralized (lost) the term for younger parallel sibling invariably replaces the term for elder parallel sibling and stands for parallel sibling, and ultimately sibling in general" (Hage 2001:205). In Figure 3 the cognate terms for younger sibling are shown in bold.

Hage's first objective was to show that similar patterns of terminological change—based on the avoidance of disjunctive categories, marking effects, and the semantic fragmentation of terminologies over time—appear in all of the world's major language families. Because the order of kin term disappearance is predictable relative to particular languages, the basic type of proto-kinship system can be reconstructed from a small set of remaining diagnostic terms within those languages. For example, the presence of a term for mother's brother is sufficient to establish that a proto-system was most likely unilineal (Hage 1998). Historical linguistics and comparative ethnography are central to this effort.

Hage's second objective was to test N.J. Allen's (1986, 1989a, 1989b, 1998a, 1998b, 2000) tetradic theory of kinship. Allen's theory posits that all kinship systems originated from an elementary system organized by bilateral cross-cousin marriage, exogamous descent moieties, and endogamous generation moieties. Tetradic systems distinguish only even generations (+2/0/−2) and odd generations (+1/−1), and are characterized by three types of kin term equations.

1. Alternate generate equations merge particular relations from one even generation with particular relations from another even generation, with odd generations similarly organized. For example, the term for parent's parent is the same as the term for child's child, merging +2 and −2 generations; the term for mother's brother is the same as the term for a man's sister's child, merging +1 and −1 generations.
2. Prescriptive marriage equations, consistent with a rule of cross-cousin marriage, merge affines and cognates, affines and affines, and cognates and cognates. For example, the term for mother's brother is the same as the term for spouse's father; the term for mother's brother's wife is the same as the term for wife's mother; and the term for mother's brother is the same as the term for father's father's sister's son.
3. Classificatory equations merge same sex siblings. For example, the term for father is the same term for father's brother, and the term for brother is the same as the term for father's brother's son.

From this basic, hypothetical system, it is possible to derive Dravidianate, classificatory, and cognatic kinship systems, based on the ordered disappearance of particular kin equations. Dravidianate systems have lost alternate generation equations; classificatory systems have lost alternate generation and prescriptive equations; and cognatic systems have lost alternative generation, prescriptive and classificatory equations. Hage's work supports the importance of

tetradic theory in kinship analyses, which proposes the ordered sequence, but also the multidirectionality, of change.

Hage's third general objective was to reintegrate the disciplines of cultural anthropology, historical linguistics, archaeology, and genetics in the study of kinship systems world-wide. His paper with Jeff Marck (2003) contributes to this reintegration. Hage and Marck define "Proto-Oceanic society" as that which "can be reconstructed, linguistically, about the social vocabulary of Proto-Oceanic-speakers and what we infer from that about their society" (2003: 123). Historical linguistics provides methods for terminological reconstruction. Comparative ethnography provides the data to make inferences about social organization from reconstructed kin terms. Archaeology and historical linguistics provide the basic framework of the dispersal of Austronesian-speakers, whose 450 or so languages most likely originated on Taiwan.[14] The expansion of Austronesian-speakers began in Southeast Asia about 3,000 B.C., reached Melanesia by about 1450 B.C. and the outer islands of Polynesia by about 950 B.C. They moved through and interacted with indigenous non-Austronesian (Papuan) populations, who had inhabited Near Oceania for close to 40,000 years, or perhaps considerably longer (Kirch 2000). Proto-Oceanic society was based on extensive exchange networks, which required extremely skilled seafarers who embarked on frequent open-ocean voyages.

Linguists and archaeologists, working from very different data sets, have demonstrated that Austronesian speakers dispersed fairly rapidly throughout Polynesia (e.g., Blust 1995; Irwin 1992; Pawley and Ross 1993; Kirch 1997, 2000). The pattern of DNA distribution resulting from that dispersal is becoming clearer. Geneticists have shown that contemporary Polynesian populations have three haplotypes (lineages) of maternally transmitted mitochondrial DNA (mtDNA). The most common of these haplotypes has a 9-base-pair intergenic deletion shared generally with Asian populations and accounts for 90 – 95% of Polynesian mtDNA (Melton et al. 1995; Skyes et al., 1995). Geneticists have also discovered three haplotypes of paternally transmitted Polynesian Y chromosomes. The most common of these, the DYS 390.3 del/RPS4Y711T haplotype, originated in Melanesia about 11,500 years ago, well before the expansion of Austronesian-speakers; it is not found in Asian or Southeast Asian populations (Kayser et al., 2000; Underhill et al. 2001). The dominant mtDNA haplotype of Asian origin is associated with Austronesian speakers; the dominant Y chromosome haplotype of Melanesian origin is associated with Papuan speakers. Having discovered the relative proportions of mtDNA and Y chromosomes in Polynesian populations, geneticists have been unable to explain the pattern.

Hage and Marck argue that matrilocal residence and matrilineal descent in Proto-Oceanic society account for the significant presence of Y chromosomes from Melanesia in the context of mitochondrial DNA from Asia. As they point out, if the Austronesian ancestors of contemporary Polynesian populations were patrilineal, "one would expect to find Polynesian Y chromosomes of predominantly Asian origin and mtDNA of mixed Asian and Melanesian non-Austronesian origin, the frequency of the latter depending on the frequency with which Austronesian-speaking men married indigenous non-Austronesian-speaking women"(2003) However, in Polynesia the clearly dominant Asian mtDNA and the significant frequency of Melanesian Y chromosomes "imply the presence of matrilocal residence and matrilineal descent in Proto-Oceanic society" (2003).

Linguistic evidence supporting matrilineal descent in Proto-Oceanic society comes from the reconstruction of Proto-Oceanic kinship terminology (Hage 1998). This terminology was bifurcate merging, with one term, *tama,* for father and father's brother, and a separate term, *matuqa*, for mother's brother. Bifurcate merging terminologies are characteristic of unilineal (matrilineal or patrilineal) descent and unilocal residence, associated with the former 85% of the time and with the latter 91% of the time (Hage 1999c).

Matrilineal descent, matrilocal residence, and long-distance voyaging were all related aspects of the colonization of Polynesia, probably additionally motivated by the practice of primogeniture. In this context, open-ocean colonizing expeditions may have been conducted by junior brothers, who were precluded from inheriting rights to ancestral resources and consequently sought their own islands to inhabit. These expeditions no doubt included women, since the intention was colonization (Hage 1999b, 1999c; Hage and Marck 2002; Kirch 1997).

After colonization, matrilineal descent and matrilocal residence persisted in many areas under conditions of prolonged male absence—for trade, or warfare, or the requirements of resource procurement (see Harris 1980, 1985 for comparative examples). Under these conditions, men who leave their social group for extended periods of time must rely on their lineage sisters to preserve and manage their common interests. Matrilineal descent and matrilocal residence, however, transform or disappear under conditions of relative social isolation, because of the inherent instability of matrilineal institutions (Lévi-Strauss 1984).

Although no longer universal in Polynesian societies, matrilineal descent and matricentric institutions remain common features. Double descent is also common, and probably indicates a shift from matrilineal to patrilineal orientations, but not the other way around (R. Fox 1983). In isolated atolls of the eastern Carolines, Marshalls, and elsewhere, where long-distance voyaging declined, patrilineal, double, or cognatic descent supplanted matrilineal descent. In some Proto-Oceanic daughter societies, bifurcate merging terminologies gave way to generational terminologies, and matrilocality gave way to avunculocality. These patterns are predictable, given a starting point of matrilineality and matrilocality.

Hage argued that the demonstration of probable paths of evolutionary change in kinship systems throughout the world provides the means to make plausible reconstructions of early human social organization. The demonstration requires the coordinated efforts of linguists, archaeologists, cultural anthropologists, and geneticists. The time depth to such reconstructions is open to debate. But surely the reconstructions can reach a time depth of 10,000 to 15,000 years, limited by the ability of historical linguists to piece together the traces of proto-languages from contemporary and historically known languages (Ruhlen 1994). The project is worth pursing for what it may tell us about kinship and social organization, and their evolutionary modifications through time.

In his "Afterword" to the volume Transformations of Kinship, Maurice Godelier makes similar observations. He notes that so-called Eskimo terminology is found in Borneo, New Guinea, North America, and emerged historically in Europe, and that this terminology has no obvious relation to any given mode of production or to any particular religious system. Given its apparently random geographic distribution, and the fact that Eskimo terminology has no correlation with other, dominant social factors, Godelier ask the general question: "how, then, are we to treat changes in kinship terminologies and systems?" Moreover, "Where are we to look for the reasons for these changes?" Godelier goes on to say:

> Are the observed transformations erratic, contingent, without fixed direction, or do they follow a certain line with no going back—broadly speaking, are they irreversible? If this is the case—and the proceeding chapters provide proof to this effect—then terminologies not only change, they evolve. Now the cat is out of the bag. Not only do terminologies disappear or change in the sense of yielding to others, but those that replace them are not and cannot be just any terminology. If this were to be confirmed, kinship terminologies could be said to succeed each other along certain possible lines of evolution, laid out by the action of a few transformation rules. Furthermore, these transformations would be such that the new forms of terminology replacing the old ones would deviate ever further in structure from the starting point; the movement would be characterized by a tendency, a drift that never returns to the starting point. (1998:392).

Per Hage's research, following the pioneering work of Joseph Greenberg, demonstrates that the rules of terminological transformation are based on an avoidance of disjunctive categories and the effects of marking. The task for future research is to confirm these rules in diverse languages and language families. A number of intriguing questions are left for further investigation. Given the apparently limited number of evolutionary pathways open to terminological change, what were the local, historically and culturally contingent motives for such changes? In contexts of rapid social changes, how resistant, or how accommodating, are kin terms to such changes? Are there terminologies that have great time depth with few if any changes? The disappearance of particular kin terms typically lags behind other changes in social organization. Does this lag time have a measurable and consistent pattern?

It may be difficult to trace with any precision the historical timing, motivation, and social consequences of changes in proto-kin terms. But, as Hage argued, with a world-historical focus on the evolution of kin terms, tools from allied disciplines—history, archaeology, genetics, comparative ethnography—can be applied to the basic data, in an attempt to better understand the relationships between kinship structures, as they evolve along particular pathways, and contingent historical events.[15] These relationships are particularly interesting in kinship terminologies, the most basic and persistent of all systems of classification.

A CONCLUSION

Per Hage's work—which spans close to forty years and covers a tremendous diversity of topics—is filled with references to prior generations of anthropologists. He felt compelled to read everything he could find on the topics of his research, in English, French, and German. He was well aware that the intellectual history of anthropology becomes lost when students are not encouraged to read what their predecessors had to say. Producing what comes after, they may not know what came before. It is easy to assume that prior generations of anthropologists were wrong if you don't bother to read what they wrote. In a response to a criticism of his analysis of the Polynesian conical clan, Hage was quite blunt on this point. Ignoring the accumulated ethnographic record, he rightly noted, does not promote the intellectual health of the discipline or provide the context for the advancement of anthropological knowledge. Under circumstances of disciplinary amnesia, elevating contemporary fieldwork to the status of final arbiter of the discipline appears to have hastened the fragmentation of anthropology, undermined the value of

comparative research, and kept work focused not on the grander themes of cultural process and structure, but rather on the themes that are of the moment—themes that briefly capture attention, such as those falling under the categories of poststructuralism, deconstruction, postcolonialism and their more recent consanguines and affines—but which then disappear beneath the waves and into the murky ocean of historical contingency that Lévi-Strauss spoke of.

By contrast I think of Hage's, and Hage and Harary's, work as an island of analytical clarity—a conclusion, of sorts, to the life of mind of these two distinguished scholars, but also an encouragement that cumulative understanding is possible in a field whose subject matter is continually changing. Let the punishment fit the crime.

NOTES

[1] Although focused on Hage's, and Hage and Harary's work in anthropology, I should also mention Harary's accomplishments in mathematics and the applications of mathematics in diverse fields. He authored and co-authored more than 700 papers and eight books, edited ten books, and founded two influential journals (Journal of Combinatorial Theory and Journal of Graph Theory). He lectured all over the world. In recognition of his mathematical contributions, Harary received five honorary doctorates.

[2] "…not only Sophocles but Freud himself, should be included among the recorded versions of the Oedipus myth on par with earlier or seemingly more 'authentic' versions." (Lévi-Strauss, 1963).

[3] As Hage and Harary (1983b:68) note in their analysis of Arapesh sexual symbolism, "Mathematical models are used in this paper not because of any wish to mathematize culture but because there are ethnographic advantages for doing so. The general advantage of group models, in contrast to thematic or typological models, is that they preserve and exploit the richness of the data rather than obliterating it through generalizations." They also suggest that "Mathematics is simplifying but in a sense far different from that imagined by its critics." Tjon Sie Fat (1998:59) makes a similar point in his analysis of Dravidian and Iroquois kin classifications: "Mathematics is about structure. It is effective because it captures the abstract form underlying the many apparently dissimilar patterns exhibited in the physical or social world."

[4] Exchange in Oceania actually appeared considerably later than its date of completion. The first academic press to accept it for publication badly bungled the mathematical notation in the proofs, rendering the mathematics incomprehensible. Per was forced to withdraw the book and start the publication process anew with Oxford University Press.

[5] For an application, see Jenkins, 2001a.

[6] For a graph G with p nodes and q edges, each of the following equivalent properties can define a tree.

(1) G is connected and acyclic. (2) G is connected, and $p = q + 1$. (3) G is acyclic, and if any two nonadjacent nodes of G are joined by an edge e, then $G + e$ has exactly one cycle. (4) Every two nodes of G are joined by a unique path. (5) G is connected but loses this property if any edge e is deleted. (Harary, 1969).

[7] The Inka also had a similar structure, based not on primogeniture or ultimogeniture but on a primary son/secondary son contrast; Jenkins (2001b).

[8] Marshall Sahlins makes a similar point about the decline of interest in kinship systems. In his 1998 Huxley Lecture, Sahlins remarks apropos Leslie White's notion of the primacy of culture: "How would an ape to able to apply, let alone devise, a marriage rule that proscribes parallel cousins and enjoins unions with classificatory cross cousins?" He goes on to say, parenthetically, "In all fairness, current anthropology graduate students in America cannot do that either." (1999:400).

[9] Notable exceptions include Nerlove and Romney (1967) and Kronenfeld (1974).

[10] Let me note that Hage had applied for an NSF grant to support the writing of Structural Models in Anthropology. The consensus among the reviewers was that the project was too ambitious and could not be completed. I suspect that had Hage not received NSF support for his kin terminology project, it wouldn't have mattered: he would have done it anyway.

[11] Murdock's typology of six cousin categories is based on the classification of siblings, parallel cousins, and cross-cousins, and on whether the patrilateral or matrilateral cross-cousin is raised a generation. The latter characteristic differentiates Crow, Omaha, and Iroquois systems.

[12] In a letter to Per dated January 12, 1998, Lévi-Strauss remarks on Hage's "Unthinkable Categories" paper: "I agree that Françoise Héritier's 'fundamental laws' are far from convincing. The 'unthinkable' terminology would be quite congruent with a system wherein a man may marry either his elder or his younger sister but not the other one. Thus from ego's point of view the same term will apply to both the mother and the marriageable FZ while a special term will be needed for the MZ who is at the same time the non-marriageable FZ. There are instances of such rules in the literature. However as this type of incestuous marriage would be the privilege of a small minority, no kinship terminology fitted for the use of the general population could possibly reflect it."

[13] "Mathematically a *lattice* may be defined in a formal axiomatic manner as a *partially ordered set of elements (nodes) in which every two nodes have a least upper bound* (LUB) *and a greatest lower bound* (GLB…. [W]e may say that a *semilattice* is a '*partially ordered set' of nodes in which every two nodes have an* LUB. We should point out that the presence of a GLB is deliberately excluded from this definition. It therefore follows that every lattice is a semilattice

but not vice versa. In this sense, a semilattice is a more general mathematical structure than a lattice. Every rooted tree…is likewise a semilattice, but the converse is not true." (Hage and Harary 1996:251).

[14] Austronesian languages number over 1,000. Of these, about 450 are spoken by indigenous peoples of Oceania (Pawley and Ross 1995)

[15] Lévi-Strauss's (1969:8) observations about myth, and his challenge to history, come to mind. "…by demonstrating that myths from widely divergent sources can be seen objectively as set, it presents history with a problem and invites it to set about finding a solution." He says further that "I have defined such a set, and I hope I have supplied proof of its being a set. It is the business of ethnographers, historians, and archeologists to explain how and why it exists." In many ways, the evidence from historical linguistics concerning sets of kin terms is stronger than the evidence concerning sets of myths. In both cases, however, the historical problems are similar, and the solutions require the coordinated efforts of cultural anthropologists, linguists, archaeologists, historians, and geneticists.

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