The Indigenous Australian Marriage Paradox: Small-World Dynamics on a Continental Scale

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Abstract

Ethnographies of Indigenous Australian language groups suggest that their populations were consistently small, averaging perhaps 500 people each, while classical models of their kinship systems consistently embody endogamous marriage as both a norm and a logical requirement. While geneticists are concerned about the potentially lethal effects of inbreeding depression in small populations, paleodemographers argue that reproductively closed small populations, whether humans or other species, are doomed to extinction due to stochastic variations in birth rates and sex ratios. How then did Australia foragers avoid extinction and persist for 40,000 years and more if each was reproductively closed as in models of prescriptive endogamy? We introduce a mathematical model of Aboriginal descent, marriage and kinship that is reproductively open rather than closed, show how the openness articulates with traditional closed kinship models, and demonstrate how the resulting system might maintain dynamic population stability despite internal and external stresses that might otherwise lead to extinction. The mathematical model demonstrates how each language group creates and maintains a local cluster in the space of a large "small world" of continent-wide marriage connections that articulate through common features of social structure and whose variants are likely to have adaptive significance in relation to sites and periods of scarcity or resource sufficiency.

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Keywords: Modeling biases, model generality, weakening of modeling axions, Natchez models, Australian kinship models, networks as models, network structure, social dynamics, demography, demographic survival, small-world, connectivity, Alyawarra, generations

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Introduction

Bronislaw Malinowski is known for his intensive ethnography based on observation of social processes and how they interconnect. Malinowski's (1922) description of the kula ring is an example of his following out the implications and the description of exchange relationships that he observed in the Trobriand context and traced out for the larger Massim archipelago. Malinowski is also known for his opposition to mathematical modeling, say, of kinship systems and to the kind of closed-system structural-functionalist models advocated by Radcliffe-Brown (1931). If we consider interconnected social process descriptions as network analysis, Malinowski's work could be considered a forerunner of "network realism" within the contemporary vogue for network modeling in the social sciences.

Dousset (2005:18) characterizes Malinowski's contextual embedding approach as one of two basic approaches used in Australian kinship studies, the other being the concern with "the structural integrity of systems of alliance and descent systems". The contextual approach integrates in its analyses "pragmatic explanations for the existence and geographic distribution of social category systems." For Godelier (1977), for example, social category systems are seen "as part of a global system, including ecological, demographic, and historical aspects, and the approach distinguished itself from the structural-formal approach through emphasizing the dynamic and dialectical aspects of social structure." We align ourselves with this view, neither to assert an integral global structure to Australian kinship nor to argue for dialectical reasoning, but simply to adopt a weaker axiom-set about networks of connections in a more open format whose properties might be discovered by close analysis of observed social processes.

Here we argue that a Malinowskian perspective engaging network realism and complexity provides a useful approach to mathematical modeling, and that Malinowski's critique of "closed system" models of social organization remains true to the mark. The approach we take is consistent with the argument of White et al. (1971, 1974) in its emphasis on weakening the axioms of theoretical models so as to capture empirical phenomena at a more general level commensurate with network realism in understanding human interaction. The antecedents and effects of interaction need to be considered in the broadest possible terms while grounded at the same time in the most concrete, detailed and culturally embedded observations of social processes.

First we review the Natchez Paradox that was resolved long ago (White, Murdock and Scaglion 1971) by weakening the ethnographic axioms embedded in the model of the paradox and of Natchez society. Then by analogy we introduce the Australian Paradox, which we resolve with a mathematical model and a dynamical system based on it.

The Natchez Paradox White's (1974) review of mathematical modeling in anthropology used the Natchez Paradox as an example of detailed open-system modeling that could identify and also correct faulty assumptions of ethnographers. As H. White (1963:28)

noted, "A weakness of anthropologists' analyses of data on existing [societies] may be that they try to force the data into one of the very few systems of which they are aware."[1]

Re-modeling the Natchez Paradox involved two very simple contrasts that opposed different axioms about kinship. While there is no question that lineages founded by sons of the ruling Sun matrilineage were considered Nobles and sons of Noble matrilineages were given the title of Honoreds, Swanton (1911) inferred as well that there were Honored daughters whose descendants formed Honored matrilines. His category mistake was to apply a principle of symmetric descent for sons and daughters as if Honoreds were descent groups rather than an asymmetric category of male *rank* that did not apply to women. [2]

White, Murdock and Scaglion (1971) posited weaker assumptions about descent consistent with the historical data. As described by the texts of French colonists living in Natchez, Noble women transmitted Noble status matrilineally only for three generations. The textual analysis of White et al. showed no evidence of Honored women in Natchez society. Compared to hundreds of references to individual Sun and Noble women in the French sources, there were none to individual Honored women and none to Honored descent groups. The details of asymmetric rank decay among the nobility described in the accounts of French colonials living among the Natchez, moreover, were consistent with the absence of Honored women. Swanton had read such accounts (Le Page du Pratz, 1758 cited in Swanton 1911:101) but discounted them because of his assumptions about descent. Thus Swanton mistakenly invented Honored descent groups. In fact, Noble status was one of rank or social class (White, Murdock, Scaglion 1971), not one of enduring descent groups.

The mathematical modeling that solved the Natchez Paradox posited two opposing sets of axioms, by Swanton (1911) and White (1974), shown in Table 1. Basic assumptions differ about what constituted descent, nobility, and rank in these two axiom sets.

	Swanton (1911)	**White (1974)**
Axioms	Descent lines in 4 groups Descending rank	Descent line for Sun rulers, with asymmetric rank decay for nobility
Groups	Suns (♀♂) lineage	Suns (♀♂) lineage
	Nobles (♀♂) lineages, rank	Nobles (♀♂) rank
	Honoreds (♀♂) lineages, rank	Honoreds (♂) rank, title
	Honoreds (♂) title	Honoreds (♂) title, achieved
	Commoners (♀♂) lineages	Commoners (♀♂)

Table 1: Weakening the Axioms of Descent for Natchez Nobility

[1] The unfortunate tendency to force data into assumed models is discussed by Leaf (2007) as an aspect of positivist approaches to anthropological methodology.

[2] Asymmetry in this respect to sons and daughters occurs among the Caddo, neighbors of the Natchez, parallel to that between Honored sons and commoner daughters of Noble men (Swanton 1931). First noted by Murdock, this was the first clue that Swanton might have been wrong in his denial of this feature of the Natchez noble descent because of his distrust of the most detailed of the French sources (Le Page du Pratz, 1758 cited in Swanton 1911:101).

Swanton's model, which does not match actual historical descriptions, produced the seeming *Natchez Paradox*: namely, in each generation excess women were added to the ranks of Honored women, who then produced Honored matrilineal descendants in their lineages. In time, the Honoreds would swell as the expense of commoners so that there would not be enough commoners for the nobility to marry under the rule of exogamy for nobility.[3]

Efforts to solve the Natchez Paradox, posed by a society that seemed to continually spawn more nobility than could possibly have been organized demographically, were abandoned after 1971 when it was recognized that Swanton had invented the category of Honored women and discussions of the "paradox" were dropped from standard anthropological textbooks. The Natchez Paradox was solved, then, not within the set of assumptions posited by Swanton, but from textual sources and using a mathematical model with less rigid assumptions about descent rules. The resultant model, using relaxed and ethnographically appropriate parameters, showed Net Reproductive Rates (NRR)[4] that were more steady-state rather than an ever-increasing proportion of nobility.

We emphasize three points here. First, mathematical models can be extremely useful as a counterpoint and theoretical sounding board as against ethnographic description, narrative history, and cultural theory. The Natchez case is one of a large class of situations where both ethnographic description and modeling introduce empirically inappropriate or uncalled-for assumptions that need reconsideration. The more extreme of such unwarranted assumptions may surface as apparent paradoxes. Second, it is often with a weakening of the axioms of models *and* of the assumptions of the ethnography that we encounter fit between models and reality. Third, it is crucial to develop *testable* propositions and to put alternatives to the test as to how models and reality should fit according to these alternatives (Chamberlin 1890). These should involve robust criteria for evaluating the fit of alternative models, the accuracy of ethnographic data and interpretations, and whether weakening empirically inappropriate or uncalled for assumptions is the needed reconsideration.

Similarly (and see also White and Johansen 2005 for a Middle Eastern case approached in this way), in examining Indigenous Australian societies, our modeling compares a) ethnographer statements about social rules with b) different data and assumptions about demography or other aspects of social processes.

The Australian Paradox Populations of traditional Indigenous Australian language groups (once called tribes) seem to have been consistently small, averaging perhaps 500 people each (Birdsell 1953, 1970; Kelly 1994). At the same time, classical models of Indigenous Australian kinship (Radcliffe-Brown 1931, Lévi-Strauss 1971) consistently depict endogamous marriages not only as the norm but also as a logical requirement of their kinship "systems" (a "logic" following from prescriptions for types of marriage

[3] Quimby (1946) argued that the anomalous feature of Natchez noble and royal exogamy, marrying with commoners, was advantageous in the expansionary phase of Mississippian civilization in terms of the assimilation of new groups.

[4] NRR = mother/daughter ratios in successive generations.

expressed in the idiom of certain classes of kinship terms). These two features together present a problem.

Small Populations. Paleodemographers such as Bocquet-Appel and Masset (1982) have argued that:

> "Any group of a limited size (under a few hundreds) is threatened to die out as a population through the mechanical action of mere random fluctuations. Such groups, in order to ensure their steady reproduction, must anastomose with others by exchanging the excess of their still unmarried members. In other words, to overcome the destroying action of the random fluctuations within a group, migratory moves are absolutely necessary from one group to the other. It is only by regulating this inter-group migratory exchange that the population will be able to survive as a whole."

Recent research dealing with wildlife conservation and the extinction of endangered species strongly reinforces their argument, and suggests that the impact of demographic and genetic stochasticity on Minimum Viable Population (MVP) size and time to extinction is even more severe than Bocquet-Appel and Masset (1982) attest. Current estimates of MVP (.90, .95 or .99 probability of survival after 40 generations) depend upon the nature of the model used to estimate it (Allen 2003) as well as on precisely which kinds of stochasticity are investigated.

Consider the following three examples: First, Reed (2005) notes that "populations will have to be maintained at sizes of >2000 individuals to maintain population fitness at levels compatible with … long-term persistence." His approach to estimating MVP size provides estimates "in general agreement with those from numerous other studies and strengthens the argument that conservation efforts should ultimately aim at maintaining populations of several thousand individuals to ensure long-term persistence". Second, Saether et al. (2004) report a more detailed analysis, concluding that demographic stochasticity is larger in a polygynous than in a monogamous mating system … [but] estimated time to extinction is considerably shorter for a monogamous than for a polygynous mating system, particularly if density regulation acted only on females than rather on the total population." [5] Finally, Traill et al. (2007) report a meta-analysis of 141 sources published since 1974 covering 212 species. They "derive a cross-species frequency distribution of MVP with a median of 4169 individuals (95% CI=3577-5129)", and conclude that "… the MVP for most species will exceed a few thousand individuals."

MVP as a genetic problem also has a notable history. Half a century ago Morton, Crow, and Muller (1956) were measuring mutational damage associated with consanguineous marriages, and geneticists of today such as Tanaka (1997, 2000) have demonstrated that inbreeding depression among very small populations can lead to their extinction.

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[5] This would reduce Reed's (2005) MVP estimate below 2,000 but still above Bocquet-Appel and Masset's (1982) estimate of a few hundreds.

In other words, truly closed small populations are reproductively doomed to extinction, both demographically and genetically.[6]

Endogamous Marriages A broad acceptance of the importance and pervasiveness of small-group endogamy in Indigenous Australian societies comes from many ethnographies that report and analyze endogamous marriage systems, including the highly influential work of Radcliffe-Brown (1931), Elkins' (1956) summation of knowledge at mid-20th century, and a host of comparable publications reviewed by Berndt and Berndt (1964), Hiatt (1996) and others. Small-group exogamy is less well documented. In the 19th century, intergroup marriages may have been over-reported (and later rejected) because of a ubiquitous and naïve assumption about "group marriage", and intergroup marriage was simply seen as a logical extension of it. In the 20th century, intergroup marriage may have been under-reported when dismissed as a byproduct of colonization and concomitant detribalization rather than as a manifestation of longstanding traditions. Hence potentially valuable data on intergroup marriage is defective or missing, biased by different assumptions at different times. The end result is an emphasis on endogamous marriage and a poorer understanding of exogamous marriage among Indigenous Australian societies.

The Paradox What we call the "Australian Paradox" is simply this: If small language groups ―as inventoried by Birdsell (1953, 1970) for example― with prescriptive, endogamous marriage rules, as traditional models of Aboriginal kinship systems posit, were a general characteristic of Indigenous Australian foragers, why would these societies not have gone extinct long ago if each was a demographic isolate?[7] Yet, small Indigenous Australian societies have not gone extinct, and small groups of foragers have evidently been thriving in Australia for 40,000 to 60,000 years. How can this be? It seems likely, *a priori*, that these groups were not fully reproductively closed as marriage models usually entail. We need, however, to examine the evidence for competing hypotheses.

To phrase the paradox positively, we ask for a solution to the following problems: It seems unlikely that the members of any natural human society would voluntarily allow their population to go to extinction if they could prevent it. So: what kinds of demographic and social processes or strategies (conscious or unconscious) would assure the continent-wide survival of largely small-sized groups of Australian foragers in the face of potentially extreme and recurring local perturbations in NRR due to demographic, genetic and environmental stochasticity, i.e., random population fluctuations and environmental stresses including upheavals produced by colonial impacts? Would not limited exogamy be likely to be commonly found among these strategies? And would not that pose questions about how kinship and marriage patterns operated in the context of intersocietal marriage, or moving to join other groups?

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[6] Mathematical models already exist that support this point both for simulated small populations (Gilbert and Hammel 1960) and for known real populations operating under closed mating regimes at small population sizes (Caldwell et al. 2006).

[7] Fully endogamous marriage with classificatory kin, that is, might support reproductively viable populations in some cases, but had this indeed been the case in Australia it would not offer a general, long-term, wide-spread, survival strategy under stressful conditions in tiny and fully closed populations.

Although our argument is firmly supported by mathematical relationships in several domains, we focus on empirical data in relation to the realm of concepts, rather than computations, thus avoiding Whitehead's (1925) Fallacy of Misplaced Concreteness.

Theoretical Background

Abstract Closure and Prescribed Marriage. Dousset (2005:13) criticizes Hammel (1960: 15) and in doing so, many other kinship modelers, in suggesting that section systems, so common throughout much of Aboriginal Australia, correspond to three basic assumptions: "first, section organization results from the permutation of lineal kinship affiliations; second, all groups of affiliates are exogamous; and third, the entire model is endogamous."[8] Other models of classificatory systems, starting from Weil (1949, 1963), and continuing through Bush (1963, from prior mimeo) and Kemeny, Snell and Thompson (1962), to Harrison White (1963), started from weaker assumptions —ones that did not include endogamy— and continued to weaken the axioms of their models to better comprehend and fit the ethnographic data. The notion of *closure* in these models comes to be one of abstract roles, not concrete groups closed under endogamy. Even White, however, like many others, confuses the *abstract closure* of a classificatory kinship system with *prescribed marriage*.

Dravidian Logic and Open Marriage Chains. The difference between these two concepts —categorical or abstract closure versus actual endogamy— did not become apparent until Lounsbury (1964a), following Morgan (1871), re-discovered the simplicity of *Dravidian logic* in the computation of kinship ties and kinship terminology. Understanding this logic begins with the observation that if two relatives trace a total of n links upward to a common ancestor, considering single chains of links, there will be f links to fathers and $m=n-f$ links to mothers. In standard Dravidian logic the two relatives are *same side* if the number of female links is even (like ego's sister) and *opposite side* and possibly marriageable if the number is odd (like a sister's child,[9] which introduces an extra mother link to sister; brother's child would be same-side). Many kinship systems have since been shown to have a Dravidian logic based on alternation of sides through maternal-links, and still others a logic based on alternation of sides through paternal links (Houseman and White 1998a, 1998b). It is also possible to have both kinds of sidedness simultaneously, as in a 4-section system. Kay (1967) produces a variant but mostly equivalent reckoning to that of Houseman and White. We have every reason to say, then, that the logic employed by many Australian groups eluded that of many of the finest kinship algebraists up to Lounsbury and remains elusive in the anthropological literature generally.

What is saddening is that since ethnographers have accepted Lounsbury's discovery of Dravidian logic, there has been a certain difficulty in separating the concepts of endogamy, prescription, and abstract closure as they apply to Australia. The difficulty seems to be that the number f can vary from one to infinity without altering the *abstract*

[8] The models of Dumont (1983), among many others, continue the assumptions of closure and endogamy.

[9] Standard Dravidian has a patrilineal bias in which ZD but not BD may be marriageable but in Dravidian with a matrilineal bias the marriageable niece is reversed.

closure of a dichotomously sided classificatory system. Every ego could have an infinite pool of potential kin-types for mates if arbitrarily long chains of ancestry are allowed, or if the number *f* is also computed for relationships that include multiple links involving in-laws or adoptions of outsiders. The potential for unlimited numbers of kin-types entails an *open marriage system* and does not require prescription in the sense of an obligation to marry only within a particular endogamous category of a spatially and linguistically localized group. In practice, however, generations of deceased female relatives are quickly forgotten in most Australian societies, which adds considerable flexibility to the management of kinship ties and terms among distant relatives.

Where Dravidian and related kinds of Australian kinship logics do occur, a better concept than prescription for evaluating marriage choices is that of *behavioral consistency* within the network of kinship ties. That is, if two people have several common ancestors in social memory, are they consistently *same side* or *opposite side* relative to ego and each other? Marriage moieties typically insure that this is the case through an ascribed rule of descent, but, as Houseman and White (1998a, 1998b) and White and Johansen (2005) have shown, consistency of sidedness in a kinship network follows automatically from egocentric marriage choices consistent with ancestral sidedness, seeded from a consistently sided kernel that may spread through a kinship network.

Both ethnographic and mathematical models of Australian kinship systems, including those formulated after 1964, are typically configured for a spatially and socially bounded group. Not only do they usually assume prescriptive marriage rules such that one can marry only within one's own group, but the prescriptions usually entail marriage with only a very limited subset —and finite number— of potential mates available within one's own language group, typically into a specific moiety, section or subsection, sometimes with close kin, sometimes with close classificatory kin, and sometimes with distant classificatory kin.

Lévi-Strauss [1949, 1971:219-220] addresses the problem of open and closed systems in another modality when he employs the notion of consecutive kinship terminology in certain Australian societies (e.g., Yaralde and Ngarinyin), which he associates with open-system generalized exchange, in contrast with alternating terminology (e.g., Aluridja, Macumba), which he associates with delayed reciprocal marriages in closed pairs of lineages. He considers the possibility of intersocietal open-system marriage chains in what is considered a region (that is, Australia) noted for direct exchange. In doing so, he raises a second and wider paradox within his own theory: if the open chains of marriage do not necessarily wrap back upon themselves within the radius of the local group, then how can we associate his concept of an "elementary" system with the concept of prescription (or was it a mistake for others to have drawn the conclusion that his prescriptive systems are necessarily endogamous)? A society in which marriage rules allow linkages with neighboring societies can hardly be called prescriptive in the ordinary sense. Our view is that the occurrence of consecutive kinship terminology is not necessarily associated with endogamy.

Solving the Apparent Paradox. Our approach to solving the Australian Paradox is based on parallels with the Natchez Paradox described above. Swanton's (1911, 1931) arguments concerning kinship and demography among the Natchez were based on strong axioms that favored a symmetrical descent system, thereby obscuring much weaker axioms that favored asymmetrical transfers of class and rank memberships. The strong axioms generated a demographic paradox that was resolved only when weaker axioms were shown to have a much better fit with the ethnographic realities (White, Murdock, Scaglion 1971; White 1974).

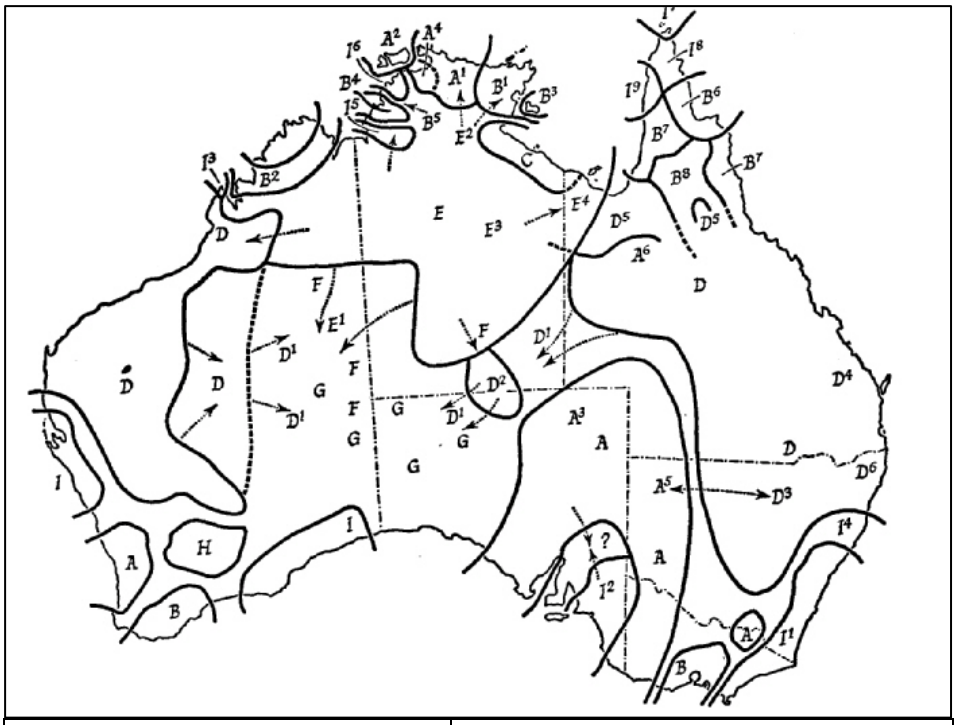
Likewise, we suggest that the traditionally strong axiom favoring mandatory endogamy and reproductive closure among Indigenous Australians generated the Australian Paradox, and that a weaker axiom favoring preferential endogamy whose intensity varies through time leads to its resolution. Lévi-Strauss (1971) took a step in this direction when he said that generalized exchange could entail chains of marriages that cross group boundaries. Recent research by Dousset (2005), Brandenstein (1982), McConvell and Alpher (2002) and Denham and White (2005), among others, also point in the direction of openness of marriage links across local groups. This approach offers avenues for resolution of the paradox, which we explore in this article.

Another approach, which we do *not* adopt here, might rely on demonstrating that population sizes really were significantly larger than ethnographers reported. If so, there would be no reason for concern. Birdsell's (1953, 1970) estimates, which have been challenged by Kelly (1994) and others, are methodologically imperfect and the results are imprecise, but are they sufficiently defective to eliminate the paradox? Birdsell's estimates have stood for half a century, during which time traditional groups and living conditions that might have yielded better data on this important question have faded into history. Perhaps Birdsell got it wrong, but there is not much we can do at this point to correct his estimates; hence we cautiously accept them.

Having weakened the axiom about endogamy, we then argue counter-intuitively that one of the main functions of widespread restrictions placed on marriages in small scale Australian social networks was precisely the opposite of endogamy and prescription. Rather, under certain circumstances and especially in times of local scarcity of mates, those restrictions facilitate the integration of regional and continent-wide populations by forcing people, at times, to marry outside their own language groups. Simply put, *local restrictions encourage the dispersion of marriages*.

Empirical Background

Theme and Variations. Moieties, sections and subsections appear almost everywhere among Indigenous Australians, with myriad variations on a common underlying theme. The map with abbreviated key in Figure 1 (Berndt and Berndt 1964:52-59) illustrates the geographical distribution of many variations on that theme, but the precise nature of the theme remains obscure despite more than a century of study (Hiatt 1996:36-56). One of the goals of this paper is to achieve a better understanding of that underlying theme.



A	Matrilineal moieties	F	Rapprochement between sections and subsections
B	Patrilineal moieties	G	Six sections
C	Semi-moieties	H	Named pairs of sections
D	Four sections	I	No moieties or sections
E	Eight subsections		

Figure 1. Distributional spread of Australian Aboriginal social organization (Berndt & Berndt 1964:52-59)

We begin our review of the ethnographic data by examining a wide range of materials on the distribution and diffusion of cultural features, moieties, section and subsection terms, and Omaha kinship terms that seem to have some bearing on reproductive strategies and openness.

Our position agrees with Dousset's (2005) general findings about Indigenous Australian networks, demography, trade and ritual in the Western Desert; with Dousset's (2005) account of the diffusion of section names in the Western Desert; with Brandenstein's (1982) materials concerning the diffusion of subsection names in northern and western Australia; and with McConvell and Alpher's (2002) material on the diffusion of Omaha kinship terms from Cape York Peninsula to points west and southwest. These authors adduce an abundance of evidence that shows how Indigenous Australian societies traditionally operated as systems that had the potential to oscillate between reproductively open exogamous systems and reproductively closed endogamous systems. In conjunction with our summary of these data, we issue a few precautions.

Intergroup Linkages in the Western Desert. Gould (1980) studies the signatures of the "risk minimizing mode of hunter-gatherer adaptation" (Dousset 2005:84-85) and

"articulates the necessity for social networks to exist and to be maintained" in and between groups. The Western Desert studied by Dousset, with its severe temporal and spatial unpredictability of rainfall, constituted, according to Gould (1969:273), "the harshest physical environment on earth ever inhabited by man before the Industrial Revolution". Requiring a fluid and adaptive social structure, "exogamy, the need or obligation to marry outside the local community, is a strong characteristic in the Western Desert, as marriage creates mutual rights of access to resources as well as solidarity between in-laws" (Dousset 2005:85). Not surprisingly, the archaeological evidence of extensive travel and trade is seen in the abundant distributional evidence for exotic materials of unique and hence traceable provenience.[10]

We agree that intermarriage almost certainly occurs between local groups in Australia, but go further than Dousset. We explain the common denominators of the Australian rules of exogamy by arguing that social rules that restrict marriage choices *locally* have the effect of forcing more mating or marriage *between groups* and thus spreading genes and reproduction into broader population distributions. This allows the greater range of choices that facilitate adjustment in NRR so that small groups needn't go extinct.

Dreaming Tracks. Dousset (2005:86) notes that "Dreaming tracks are likely to overlap with trade routes, and routes of cultural diffusion are evident. Ritual activities take place at specified locations along these Dreaming tracks, and, as Myers (1986:173) writes: 'If anything, the ritual life is even more devoted to formal exchange than is daily life. The exchange of sacred objects between men makes the principle into a goal itself.' " Further, "ritual knowledge itself is a 'traded' good, as groups exchange… [and] many of the significant sites of Dreaming tracks are located at the stopovers during people's movements." A "phenomenal number of such tracks … criss-cross the most remote areas of the desert and beyond." Dousset maps out some of the more general directions of such routes to demonstrate his thesis of the diffusion of section systems and terminologies along routes of intensive intergroup contact.

Dousset is persuasive, but relaxed axioms require us to raise another cautionary flag; namely, that the diffusion of section systems and section terminologies should not be regarded as necessarily coterminous.

Ritual Interactions at Boundaries. Dousset (2005: 15-16) asks us to recall that, "as Radcliffe-Brown (1931) and Scheffler (1978) have stressed, the section system is not the basis of rules of marriage [e.g., behavioral prescriptions] or descent. Sections are a ceremonial, sometimes totemic, labeling device that is overall compatible with kin-classification." For example, some categories of female kin in the section of a male Ego's intermarrying section (such as MBD, FZD, DD and FM) are not classified as "wives".

Dousset's (2005:78-79) account of the diffusion of section terms and/or sections in the Western desert underlines the "inherent diffusionist capacity of the section system itself,

[10] This and other discussions of intergroup marriage in Dousset 2005 and Brandenstein 1982 are valuable and highly suggestive, but they rest necessarily on anecdotal rather than statistical data.

linked to its ability to regulate behavior between 'foreigners', including within ritual exchange" between different groups.

Diffusion of Four-Section Names. Here we summarize Dousset's (2005) interpretation of the diffusion of four-section names in the Western Desert. We then apply his interpretation, judiciously, to Brandenstein's (1982) somewhat controversial work on eight-subsection names in northwestern and northern Australia. We conclude this part of our review with a summary of McConvell and Alpher's (2002) report on the diffusion of Omaha kinship terms across northern Australia. We are not concerned with linguistic details, but rather with large-scale patterns of diffusion that appear to have moved across the continent from various inferred points of origin during the last two centuries.

Dousset's study leaves no doubt that section names diffused throughout the Western Desert. Although we question the auxiliary assumption "that the four-section system diffused along with the associated terminology," we heartily agree that this terminology may vary (p. 33), and we readily concur from his evidence that "when a new term replaces one of the existing terms" the new and the old term have the *same valeur* of a section, which means that the two are structurally equivalent in relation to other sections, and thus both cannot co-occur without one replacing the other or the two differentiating in meaning.

Dousset uses the *identity of valeur* as an hypothesis, in the context of inter-group marriages, of "how and where a term was eliminated because it was considered to be in a structural position in the system identical to that of another section it encountered during its diffusion." His tables 3 (p. 42) and 4 (p. 52) show that when there is zero co-occurrence of two section-terms across local groups in the Western Desert, there is also zero intermarriage, i.e., prohibition of marriages within sections that are structurally the same in terms of their relations with other marriageable sections. Table 2 compares his findings to allows us to measure the strength of this correlation (R=.64) and note its statistical significance (p=.00023).

Co-occurrence of Sections (p42)	0	1	2	3	4	5+	Totals
0 Inter- marriages (p.52)	6	2	1	1	2	3	15
1		1		1		2	4
2-9						9	9

Table 2: Non-co-occurrence of section names correlated with lack of marriages

Dousset's analysis again is solid, but we are troubled by his evidence that "the four-section system diffused along with the associated terminology" in the period that Dousset studies and not earlier (and possibility much earlier). This conclusion is confounded by two problems that are coterminous with how we interpret ethnographer statements that particular section systems were "unknown" before a certain date, according to informants.

One problem is that neither the informants nor the ethnographers made clear distinctions between the introduction of a new section-system terminology and the first introduction of a section system *per se*. One would need to have both the terminology and the rules of exogamy for the earlier system to decide whether one variant of a section system was replaced by another.

A second problem is that some Australian ethnographers, intent on analyzing cognitive systems and ignoring behavioral processes, have been adamant that moieties or sections do not exist if they are unnamed. Network analysis, however, including blockmodeling methods, can reveal behavioral and logical components of section systems without necessary reference to named groups or kinship terminology. For this sort of analysis of data from the Alyawarra, see Denham and White (2005), Kemp, Griffiths and Tenenbaum (2004) and Kok and Domingos (2007).[11] Australian ethnographers might not have envisioned this possibility at a time when computer-based techniques for network analysis were lacking. These studies demonstrate conclusively the independent existence of behavioral manifestations of moieties, sections and subsections while the mathematical theorems on which they are based prove that the logical and behavioral manifestations of moieties, sections and subsections are coterminous and merely *entail* the possibility but do not necessitate consistent naming. To insist that all patterns in behavior must be named by their possessor in order to exist is another fallacy of misplaced concreteness. Logical, terminological and behavioral components of moiety or section organization, that is, can and should be examined separately and compared. Imperfections in the rendering of each may also vary independently.[12] These empirical findings weaken a ban against the concepts of implicit moieties, sections and subsections insofar as it might apply to the study of logical and behavioral components.

Dousset (2005:29) questions what becomes his own conclusion; viz., that societies observed as changing to a new section system are in transition from a previous one, saying that "Eliminating this … hypothesis is more difficult." His argument rests on his interpretation of "transition" as a characteristic of an unstable system, which he rejects by showing that the system "borrowed" in one case was previously recorded as "stable" in a neighboring group. This does not rule out that a prior terminological system in the receiving society was not a section system, even if only behaviorally. The statement of Tindale (1965:98, cited by Dousset 2005:29) for the "Nakako" of the Mt. Davies area having "no class system until 1933" —i.e., they did not distinguish cross- from parallel— is equivocal without an examination of the earlier terminology and rules of exogamy.

We argue for a deeper understanding of the relational logics of section systems, named sections, and kinship terminologies. To define a section system we quote from an Australian legal authority (Fryer-Smith 2002:2.9):

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[11] Similarly, White (1997) and Houseman and White (1998a, 1998b) analyzed marriage patterns in terms of the commonality of the two-sidedness of many empirical kinship networks in societies with Dravidian terminologies. Two-sided marriage networks in the absence of named moieties are common.

[12] White and Johansen (2005) devote the first chapter of their book to these points, with the caveat that while perfect adherence to a local rule of behavior in a social network, for example, may entail a perfect global structure, and vice versa, variants or errors at each level are mutually entailed but harder to analyze.

> "Moieties are exogamous: each person in the group marries a person from the opposite moiety. Membership of a moiety is significant in ritual and social interaction within the language group, as well as in the making of appropriate marriages. Where divisions based on moieties and generational systems are combined to make four divisions, a "section" system is created. Sometimes two of those four "sections" are divided, creating six divisions: this system exists in the Ngaanyatjarra community of Western Australia.
>
> A "subsection" system is created where four "sections" are further subdivided to form eight divisions: "subsection" systems exist in the Warlpiri community in Central Australia and the Yolgnu community in Arnhem Land. In other areas, further subdivision into even more categories may occur.
>
> The traditional social classification systems of Western Australia are many, diverse and complex. Both patrilineal and matrilineal descent is common: some groups have local "totemic" affiliations rather than moieties or sections."[13]

Sections can be defined more precisely as complete sets of alternating generations within a unilineal descent group or within a coordinated class of unilineal descent groups with a common notion of generation.[14] Dousset (2005:30-31) notes that "The main social category classification used by all Western Desert groups is generational moieties", that is, endogamy with the alternating generations consistent with sections, and marriage prohibitions between adjacent generations, odd numbered with respect to ego. Further, he notes that the Western Desert groups exhibit a "vast number of shared cultural traits, including … elements of the Aluridja-type kinship system." Dousset (2003) uses the fact that the Aluridja kin-term system existed *prior* to the dates mentioned by ethnographers for the advent of named sections to argue that sections were not present *prior* to the naming process. We regard this as an instance of the common anthropological error of failing to understand that moieties and/or sections may exist behaviorally even if unnamed. In addition to the marriage-behavior patterns of moieties or sections and the naming of moiety or section groups, however, an additional complication is the logic of kin-term systems, which may follow patterns that are consistent with moieties or sections.

Comparing Dousset's agreement with the definition of the canonical Dravidian kin-term logic (Tjon Sie Fat 1998:70) that may occur when the cross/parallel distinctions of four-section logic (e.g., Liu 1986:140) are present, Figure 2 reproduces Tjon Sie Fat's (1998:70) coding of the Dravidian cross/parallel distinction and superimposes within the dotted rectangles their correspondence to the structural distinctions for Kariera section conceptual and behavioral logics (Liu 1986:140) for ego's and higher generations. It is widely recognized that Dravidian kin-term logic is consistent with the sociocentric logic

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[13] The quote continues: "The many different systems of social classification in Western Australia are broadly indicated in the map on the following page" but the map is missing from the publication.

[14] Sections then combine with rules of exogamy to define section systems, as with two matrilineally exogamous groups ("moieties") with patrilineal sections that might form a four-section marriage system if marriages are within coordinate generations defined by section membership. Our Figure 3 will provide a more grounded definition in terms of how this applies to kinship and marriage networks.

of exogamous moiety and section divisions. (The discussion of sibling sets and kin terms, below, makes clear how this consistency plays out for lower generations.) There is thus no evidence that Dravidian terminologies and therefore section system classificatory logic was not present long before the diffusion of new section terminologies noted by Dousset.

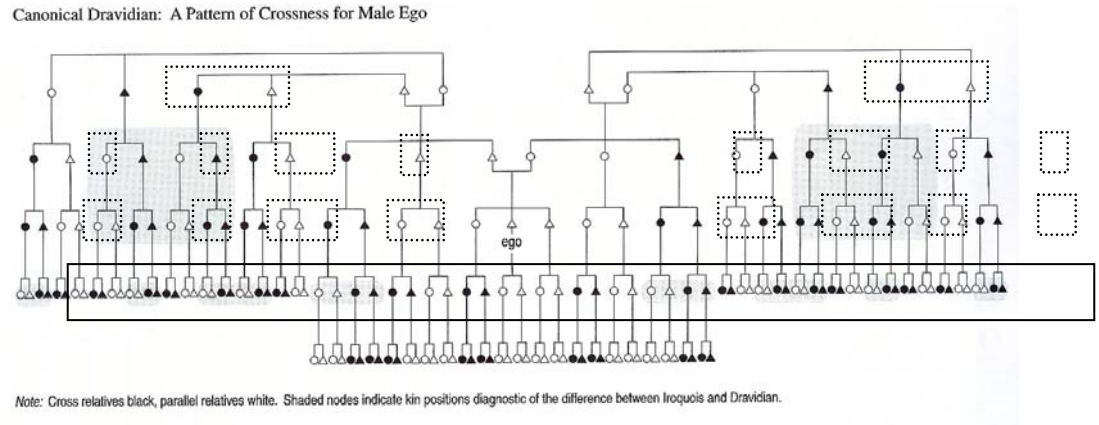

Figure 2: Section Logic and Cross/Parallel Terminology in Canonical Dravidian Adapted from Tjon Sie Fat (1998:70) and Liu (1986:140): the moieties here and their sections are patrilineal; cross-kin for ego's generation and above are shown in rectangles and correspond to section logic for both patrisections and alternating generation moieties and their matrisections. In the generation below ego cross/parallel distinctions are inherited according to the generation descent rule. The grandchild generation contrasts are matching reciprocals for grandparental terms. The figure constitutes what Trautmann (1981) and Tjon Sie Fat call "Dravidian A" or canonical crossness. In "Dravidian B" the grandchild distinctions continue the inheritance rules and are consistent with marriages to cross-kin in this generation.[15]

Dousset himself (2003:53) states that sections "are basically compatible with Dravidian kind of cross cousin calculus." Thus, even if his argument is that the *naming* of sections is recent, the ubiquity of Dravidian distinctions in kin terms generally speaks against a recent introduction of the section system *logics* to which they bear deep resemblance.[16]

*Austro-Dravidian***.** We note further that Australian section systems usually rely on Dravidian kin terms (Tjon Sie Fat 1998:70, Dousset 2003). Studies in South Asia, however, show that Dravidian kin terms (e.g., Houseman and White 1998) do not always entail section systems. One difference is that in South Asia Dravidian kin terms are most consistently used among consanguineal kin (divided into Dravidian cross and parallel) and that affinal kin are similarly divided, even if not consistently, by the cross/parallel

[15] Apart from the A and B distinction, may of the features of Figure 2 are reversed in the matrimoiety variant of Dravidian terms which is neither discussed in this paper nor Tjon Sie Fat.

[16] We strongly agree with Dousset (2003) that Elkin (1938-4) misunderstood the Aluridja kinship terminology in claiming that distant Dravidian parallel cousins such as MFZSD and MMBSD, with kin terms glossed as 'sister' were marriageable, and with Dousset's clarification of the confusions surrounding the contrast between Dravidian and Iroquois types of kin terminology. We also concur with his observation that Dravidian systems may occur with specific affinal terminologies, as observed by Liu (1986:143-145) and others, and with his distinctions regarding sociological contexts of kin-term usage (such as calling a cross-cousin 'sister' because she is same-generation, which was the source of Elkin's confusion) and interrelational contexts that refer to genealogical positions.

distinction but using the same terms for affinals as for consanguineals. In Australia the use of cross and parallel Dravidian terms is equally and often strictly consistent for both affinals and consanguineals, given the logic of sections, but there may be a separate set of terms for affinals. We suggest that the newer label for "Austro-Dravidian" kinship terminology might be worth adhering to so as to distinguish these two variants in the use of Dravidian logics, which share the canonical distinctions in Figure 2 for consanguineal relatives, but differ in affinal terminologies. South Asian Dravidian language speakers do not use an affinal section system logic although some do employ concepts of alternating generations similar to those of Australians (Parker 1988).

Our view of the prehistory of section logics is consistent with Dousset's (2005:90) view that "the principle of section combinations adapts itself well to situations in which different terminological systems meet, and that adjustments and transformations are in some cases necessary and inevitable if the structural integrity of these systems is to be maintained over time and space." Again, our view aligns with his statement "there is a certain logic in the rules of substitution, such that, for example, if two sections in a given region may substitute for each other, they characterize a relational identity and are not ruled by filiation or marriage."

Dousset is arguing, as are we, for a weakening of axioms about section systems. An extremely pertinent comment of his relevant to weakening of axioms is that as section terms are borrowed, often replacing with the same *valeur*, the identity of *valeur* relations is lost over their routes of transmittal, and when the same pairs of terms that once shared the same *valeur* meet again their *valeurs* may differ.

Diffusion of Eight-Subsection Names. Dousset's (2005) work with section systems in the Western Desert rests in part on Brandenstein's (1982) analysis of linguistic data pertaining to subsection systems in Central and Northwestern Australia and adjacent regions, which in turn rests on earlier publications by Elkin (1956) and Meggitt (1962). Collectively these works paint a coherent if incomplete picture of the diffusion and transformation of section and subsection systems while differing significantly in detail.

After discussing the continent-wide distribution of moiety and section systems, Brandenstein (*passim*) suggests that subsections originated among the Kariera, in the Kimberly District, where the roots of the section systems are found also, or among some of their neighbors. "The section system moved south in Western Australia penetrating with difficulty the Western Desert, whilst the subsection system … moved eastward more rapidly than the sections moved south." He argues for "an independent origin of sections in eastern Australia despite their similarities to those in the west" (Brandenstein 1982:71). The tja/na prefixation of subsection names originated at the border of section and subsection areas east of the Great Sandy Desert.

Brandenstein disputes Meggitt's (1962) suggestion that "The Wailbri probably borrowed the typical section system first" before adopting the subsection system that came to them from the northwest, arguing instead that indigenous eastern section systems, ones different from western section systems, pre-existed the incoming subsection systems in

Central Australia. Hence the western subsection terms could have spread into Central Australia without the preliminary diffusion of western section terms into the region. The diffusion of subsection terms then proceeds northeastward from the Kimberly District into Arnhem Land, and northeastwards from Central Australia toward the Gulf of Carpentaria.

The thrust of Brandenstein's argument seems to be that the pre-existence of moieties and sections facilitated the diffusion of subsections. The diffusion of subsections did not entail radical transformations of older systems of descent, marriage and kinship, but rather the new terminology fit comfortably in place on top of existing moiety or section terminologies that were compatible with the new ones. In some cases a moiety (or section) name was equivalent to a pair of section (or subsection) names, in other cases the terms were the same or similar but their logical relationships were different, such that converting from one to another required a shift in logic. But the underlying commonalities of moiety, section and subsection systems facilitated transitions from one to another. Without endorsing Brandenstein's theoretical interpretation of subsection names, we nevertheless accept the copious data he presents (Brandenstein 1982:75-81) concerning the ease with which members of various language groups have resolved mismatches in subsection names, and systematically altered or inverted logical relations among moieties, sections and subsections, especially when marriages or other population movements have occurred across group boundaries. Here as elsewhere Brandenstein implicitly employs Dousset's concept of *valeur* to account for the matching of marriage classes despite sometimes major differences in their names and logical interrelationships.

Brandenstein focuses his discussion of subsections on linguistic evidence concerning their names and meanings, then goes beyond that to reconstruct probable routes by which subsections diffused from their supposed origin in the Kimberly District, but he does not suggest what might have motivated or powered the spread of these alternative terminological systems from place to place throughout much of Australia.

Diffusion of Omaha Kinship Terms. McConvell and Alpher's (2002:159-175) discussion of the diffusion of Omaha kinship terms across much of northern Australia focuses specifically on kinship term roots for uncles, aunts and cousins among languages in the Pama-Nyungan language family that covers seven-eighths of the Australian continent (2002:159), excluding most of Arnhem Land. They introduce linguistic evidence of historical changes in the usage of Omaha kinship terms that lead to the dispersion of alliances (p.174) under conditions of environmental stress. If we now consider our original hypothesis, in two parts, we can see that such dispersions may be adaptive.

McConvell and Alpher (2002:162) argue that Omaha skewing is a form of polysemy by which a kinship term has two senses, covering adjacent generations. Typically it entails "the extension of matrilateral kin terms to adjacent generations patrilineally, a system that occurs widely around the world and is quite widespread in Australian Aboriginal groups, although not so frequently reported in the literature" (p.161). Omaha skewing manifests

itself in several ways, including a typical form in Northern Queensland and elsewhere in which MBD (MBS) can be called M (MB) (p.162).

Reports concerning the geographic distribution of Omaha skewing suggest that the phenomenon may be discontinuous (or locally under-reported), but is widespread. It occurs in Queensland in Cape York Peninsula (2002:159) and in some languages around the southern Gulf of Carpentaria (p.170). It is found in Central Australia (p.170) among the Warumungu and among some Arandic speaking peoples including the Alyawarra (Green 1998:63-67; Yallop 1977:154). The most widely known Omaha skewing occurs among the Ngarinjin (Radcliffe-Brown 1930-31) of the North Kimberley District in northwestern Australia (p.170). "Some [Omaha] characteristics extend as far as the Aluridja system of the Western Desert" (p.171).

Detecting Omaha skew may not be easy. In the Gurindji system of the Northern Territory, "skewing is not immediately apparent because elicitation will produce a separate term for 'cross-cousin': *parnkurti* or *pakutu*." McConvell, however, after being with the Gurindji for some time, noticed that "some people who he thought would be called 'cross-cousin' (MBD and MBS) were in fact called *ngamayi*, 'mother', and *ngamirni*, 'mother's brother', respectively. When asked why this was, people said that they did this with 'actual' or 'close' relatives of this type, who were not potential affines" (2002:170-1). Observations such as these fit parts of our solution concepts for the apparent marriage paradox, namely that *local restrictions encourage the dispersion of marriages*.

The northern linguistic boundary of Omaha skewing is clear. In the northern part of the Northern Territory, a radical disjuncture between Omaha systems to the south of the Victoria River District and Iroquois systems to the north "runs clearly along the line of the major linguistic boundary in Australia, between Pama-Nyungan and non-Pama-Nyungan languages" (p.171).

Omaha skewing is broadly characteristic of Dravidian kinship systems, while Iroquois skewing is the direct reverse of the Dravidian pattern (p.171). "There is a long tradition of associating Omaha skewing with patrilineal institutions" (p.173), and McConvell sees a "strong expression of patrilineality as a characteristic of a number of the societies that have Omaha skewing in northern Australia" (2002:173). "By contrast, Iroquois crossness as found in some non-Pama-Nyungan groups fits very poorly with unilineal institutions like moieties". Unfortunately McConvell and Alpher provide no quantitative data concerning these and related topics for little data seem to exist.

Recent history of Omaha skewing appears to be complex. For example, among the Walpiri evidence suggests that skewing occurred long ago but is dead now, whereas it is alive in some nearby groups. "This pattern, which we believe might be replicable for other instances of skewing, tends to support Kronenfeld's view (2001) of Omaha skewing as an 'overlay' that can appear and disappear relatively easily as an addition to a more basic system" (2002:172). Again, this supports our hypothesis.

Linguistic evidence for place of origin of Omaha skewing points to Cape York Peninsula in northeastern Queensland. Evidence suggests that the proto-system distinguished junior and senior aunts and uncles and emphasized matrilateral junior cross-cousin marriage, which is unusual in Australia and found systematically only in north Queensland (2002:172) among groups such as the Wikmunkan. This pattern "accords with other indicators that the probable homeland of the Pama-Nyungan language family was in north Queensland" (Evans & McConvell 1998).

McConvell and Alpher's (2002:173-4) account for the diffusion of Omaha skewing as a way in which populations expand their interactions with neighboring groups, postulating "upstream" and "downstream" spread. "Upstream spread" entails movement out of well watered areas into the more arid inland, the development of more mobile patterns of subsistence and social groups, and migration into or through sparsely populated zones. "Downstream spread", often following on the above, features movement back into well-watered areas with existing populations and language replacement rather than migration as the main form of language spread. They infer that Omaha systems seem to develop and be sustained and strengthened in groups that are expanding into other groups' territories, as in the case of "downstream spread" where the incoming group needs to gain a foothold in new territory by means of expanding marriage. In conclusion they note that, "Omaha skewing and matrilateral cousin marriage may go together, not because they have a logical connection with each other, but because they both function in similar ways in expanding systems."

McConvell and Alpher's specific explanations based on upstream and downstream spread are essentially local, while their general explanation that usage of Omaha kinship terms leads to the dispersion of alliances (p.174) under conditions of environmental stress is global. We have reservations about their local explanations, but are in full agreement with their global explanation.

Where specific patterns of occurrence of Omaha kin terms among the Alyawarra (Denham, McDaniel and Atkins 1979) place restrictions on marriage into the category of potential wife, it is also evident that the selective imposition of Omaha terms can force people to marry out of a seemingly prescribed category in a context where there is the alternative of marrying outside the language group. Our most recent study (Denham and White 2005) shows precisely this: a series of open-system sibling-in-law chains moving systematically in one direction from predominantly Alyawarra marriages to a series of transitional Alyawarra-Aranda marriages, and then to predominantly Aranda marriages for individuals living on the Aranda side of the territory, all in a systematic succession of perfectly well-behaved marriages with regard to section rules.

McConvell and Alpher's broadly focused presentation of data on Omaha skewing in much of northern Australia combined with their global explanation of the phenomenon, plus our own findings, contribute strongly to resolving the "Australian Paradox."

Conclusions about diffusion and continent-wide kinship features. Is it simply coincidence that diffusion of all of these major features of Indigenous Australian social

structure have been inferred to have begun in the 19th or 20th century, or at least recently enough that we are surrounded by unambiguous evidence of the events? Is it simply coincidence that their basic structures and processes share a certain sameness even though their details differ? Is it plausible to assume that each of these is a unique and isolated event, without connections or relevance to each other? Perhaps we could invoke the European invasion as the "trigger" that initiated them since that might be the only external event that was sufficiently widespread to impinge on all of them, but without understanding how the invasion triggered the diffusions, this suggestion sounds like *deus ex machina*. We suggest that all of these diffusion processes are pieces of the same indigenous puzzle, that Dousset's argument for the presence of reproductively open systems in Western Desert societies applies to a very large percentage of Aboriginal Australia, and that his argument most likely applies not just to recent times but for a period measured in millennia.

Our principal hypothesis divides into two parts. *First,* that the greater the imposition of successively greater restrictions imposed by moieties, 4-section and 8-section systems (also known as marriage classes and skins), Omaha terminological restrictions, and other proscriptions against closer as opposed to more distant classificatory relatives, the greater the pressure to "open" the marriage choices to include a broader assortment of groups, including marriage with members of neighboring language groups. *Second,* the imposition or removal of such restrictions, which may offset the difficulties of our Australian paradox, is variable. More local restrictions may help to assure more out-marriages when mates or resources are scarce, and periods of greater access to resources and choice of potential spouses in appropriate social categories may lead to relaxation of restrictions and less out-marriage.

The Mathematical Model: How it is Built

Ethnographers often err in their descriptions because of faulty definitions and assumptions too stringent to apply accurately to what they want to describe or understand. We have reviewed a large body of data that establishes the value of adopting more relaxed axioms than are customary in the analysis of Indigenous Aboriginal kinship systems. By *relaxed axioms* we mean ones that have explanatory and descriptive value without extra baggage by which they lose generality, accuracy, and value for comparisons. The models derived from them should remain consistent with the observed data but also help to give a more general account or understanding than a narrower model derived from axioms that are too strong.[17]

Here we introduce a "relaxed" mathematical model for variants of traditional Australian descent, marriage and kinship. It weakens a) the concept of *generation* by eliminating European constraints that do not apply to Indigenous Australians, b) the concept of *endogamy* so it is no longer a mandatory requirement but rather is an optional preference whose intensity can vary through time, and c) the anthropological prohibition against discussion (some of which is valid and some not) of *implicit* moieties, sections and

[17] For a review of pervasive misunderstandings about formalization, see Jeroen Bruggeman, 2002, http://users.fmg.uva.nl/jbruggeman/appendix3.htm. See also White (1974).

subsections with regard to logical and behavioral relationships (but allows "implicit structure" to be identified in terminological systems, with which we do not demur). These three simplifying assumptions have major impacts on our ways of understanding section systems, kinship terminologies, marriage rules, marriage practices, and the concept of marriage prescriptions. These "loosenings" of our concepts and models allow broader discovery and thus greater emphasis on shared features of Australian kinship. They shred or drop axioms that are ill suited to solving the problems of understanding how kinship is constituted in these societies very differently than in ours. One of the most telling instances of these differences is our weakening of the European concept of generation to suit Indigenous Australia.

Weakening the Concept of Generation. Generation is important in Australian kinship and ethnographers tend to agree that an alternating generation logic is one of its most common features (Dousset 2005). But Australian and European generations are strikingly different. Differences of average age between spouses and of average ages of marriage for brothers and sisters are much greater in Indigenous Australia than in present-day European societies[18]. A culturally sensitive model of Australian kinship is obliged to weaken European assumptions of generation in terms of number of steps to a common ancestor and the notion that husband and wife are same generation and roughly same age. The European notion of members of a "generation" all marching in step, roughly contemporaries, as if each new set of offspring marry within their own generation, is necessarily loosened in ethnographic notions of Australian kinship. Conceptually and culturally, Australian kinship is characterized by strong notions of the unity and equivalence of siblings, disregarding differences in age.

Although generational unity of siblings plays minor roles in European kinship, as an ordering device in recording generations from a common ancestor and in reckoning the generational levels of cousins, European assumptions about similarity in ages of those belonging to the same "generation" tend to permeate the way anthropological kinship diagrams are drawn, even by Australian ethnographers who well recognize that alternating generation "sections" entail a very different concept of generation. European-style diagrams for Australian kinship, as in Figure 4, for example, often lead to confusion when it is not merely the kinship terms but the marriage patterns that are depicted.

The extent to which sisters marry at a younger age on average than their brothers varies in Australia and this variation is significant. Tjon Sie Fat (1983) shows how the averages for male and female age of marriage produce differences in the average inter-generational

[18] Mean age differences between spouses, hence sex-based differences in mean age at first marriage and at birth of first child, have varied geographically and historically in Europe (Goody 1983 *passim*; Herlihy 1985:103-111; Laslett 1971:84-112; Shorter 1977:337-339) and in other cultures worldwide (e.g., Binford and Chasko 1976:74-75). Such variations modify precisely what "generation" means in these diverse contexts. Yet the poorly defined (or undefined) Western folk concept of "generation", based on stratified individual parent-child relationships and generalized uncritically to apply to all human societies at all times regardless of their sizes or structures, continues to be used as if it were a universally applicable technical term. Our paper addresses this problem by distinguishing minimally between "stratified" and "age biased" generations. Note that, in both the European and Australian cases, average age of brothers and sisters, unlike husband and wife, do tend to converge, barring age and gender biases stemming from infanticide.

time lengths for males and females that are often sufficient to warp the structure of normative kinship relations to reflect this difference.

How then to define generation? The key element of Australian generations and of sections or alternating generations is that generation is conceived as a single unambiguous entity (barring certain kinds of 'wrong' marriages) in a classificatory sense. This is a totally different conception of generation than European "generations." But how is this synchrony of generation achieved if there are great variations in the birthdates or ages of members of the same generation? The great variations of age in sections composed of alternating generations provide a clue, *in that each section has a relatively full age-range of potential mates*, and such age differences in generation would amplify if applied (counterfactually) to include the concept of generation for deceased relatives. A workable definition of generation must not only recognize but build upon this variability in ages.

Figure 3 illustrates a very general definition of Australian generations: they consist of chains of sibling sets connected by marriage. Further, it focuses on differences in the average age of marriage of brothers and sisters, which tends to vary roughly, although with wide latitude, with the average age differences between husbands and wives. When, on average, *sisters marry for the first time much earlier than do their brothers*, as shown in the figure, they create chains of in-law relations that are also age-skewed if followed in a consistent direction. If we follow in-law relation-chains in a particular direction, such as successive WB links (e.g., WB-WB-WB-WB, as shown in this example from upper right to lower left), the age-skew average slope of a generation that includes spouses and siblings, as shown by the large arrow in the figure, is a function of time-of-marriage differences between brothers and sisters, concomitant with that between husbands and wives. Unlike the typical European concept of generations as approximate contemporaries, Australian generations can be skewed through time by greater or lesser degrees.

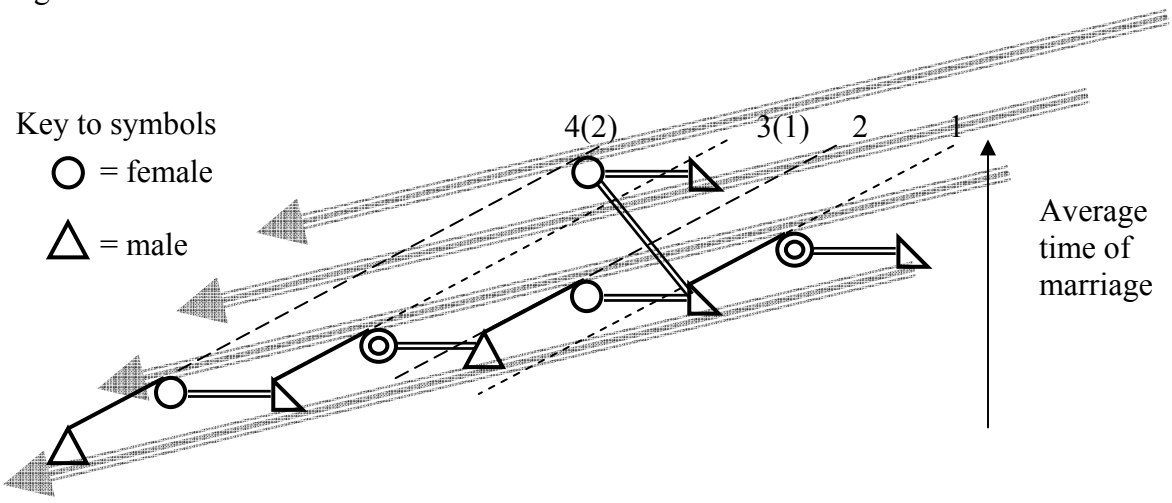

Figure 3: Structural Time and Generation for Siblings and their Marriages. This graph illustrates an elementary and consistent definition of generation involving chains of sibling sets connected by marriage. In this illustration the

consistent alignment of the chain of successive wife's brother relationships (WiBrWiBrWiBrWiBr) illustrates how same-generation might not imply contemporaries but a systemic age skewing within a generation, one which also includes classificatory alternate generations. One of these men has two marriages, for example, in this case a senior wife, so as to illustrate widow remarriage and how marriages may occur between alternative generations (the same could be illustrated for a man taking a wife from two generations below his own). A section system is formed given sibling-in-law generations in this form (in alternating generation moieties) if there is also a rule that a man and his FaFa (reciprocally, a man and SoSo) must belong to the same alternating generation.[19]

- The triple-arrow lines delineate boundaries between generations as they apply to marriage patterns. The man taking a widow and then a younger wife is in the same alternating generation as the widow and her (deceased) husband.
- Single lines in the figure link male and female siblings who on average are the same age, but these lines are drawn diagonally to reflect the fact that sisters generally marry at earlier ages than their brothers. Hence the figure reflects the same average ages of brothers and sisters in chronological time, even though as in this example generation time for females might be half that of males. [20]
- Double lines in Figure 3 show marriages. These lines are placed horizontally in the figure because a given marriage occurs at the same time for husband as for wife. Because sisters marry younger than their brothers the average difference in age of sisters-in-law and of brothers-in-law equals the average age differences between brothers and sisters.
- Dashed lines in the figure follow the slant of the schematized sibling links to emphasize age differences between sibling sets. [21]

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[19] Mathematically, this alternation is a modulo 2 rule, where modulo *k* simply refers to what is left over after division by *k*, in this case for *k* 2. Hence (4 modulo 2) = 0 = (2 modulo 2), while (3 modulo 2) = 1 = (1 modulo 2). Using modular algebra we could say that integer *a* is congruent to *b*, (modulo *n*), meaning that *a* and *b* have the same remainder when divided by *n*.

[20] We have shown elsewhere (Denham, McDaniel and Atkins 1979, Denham and White 2005), how the Alyawarra average difference between husband and wife of 14 years is coupled with average same-gender intervals between generations of 28 years for women and 42 for men. Note that the 28-year figure seems high, for example, because it reflects the time between a woman's birth and the average time-lag to birth of her daughters. There are three subcategories of marriages embedded in the average: (1) a large group of men with somewhat younger wives whose marriages cluster right around the 14-year mean; (2) a small group of old men with very young wives whose marriages cluster around a 28-year mean age difference, and (3) another small group of old men who are married to old widows. These last marriages cluster around a 0-year mean age difference and in a few of these cases the wives are slightly older than their husbands.

[21] In Figure 3 we see some sibling pairs (representing average age-positions in their respective sibling groups, but again we could be more precise and separate out each sibling or half-sibling in a network diagram) that are connected by marriages, and arrange them to represent an *age skewed generation*, shown by the large slanted triple arrow. Within an age skewed generation, successive sibling sets can be ranked by expected age differences in that a wife's brother typically marries at a later time than ego (that is, ego's wife is typically younger and her brother will on average marry at a later age than ego). The age skewed generation in Figure 3 is ranked 1 to 4 in order of age seniority, and women marry men from an older "ranking," husbands taking wives from a younger one. *When brother/sister ages are skewed, there can be men of marriageable ages in any of these rankings* as in the lower part of the figure and in any of the age skewed generations.

The potential for age difference shown is Figure 3 is crucial for any culturally realistic modeling of Indigenous Australian kinship. Focusing on the single generation composed of sibling and first-marriage relations, successive marriages in a directed chain of sibling-in-law relations may become further and further apart. The generational equivalence of positions of sibling sets in such chains follow a classificatory logic of alternation between exogamous sibling sets within each generation.

Weak Axioms for Modulo Divisions of Sibling-in-Law Chains. As with alternate generations and Dravidian terminologies, there are variants of modulo rules —in this case the alternating division into 2 of successive sibling-in-law sets along chains of marriage— for genealogical kin. The variety of ways modulo rules for marriages among sibling sets in these directed chains can be phrased is in terms of idealized series of marriages: directed a,b,c,d (modulo 4) links, directed a,b,c (modulo 3) links, reciprocal a,b links (modulo 2), and so forth.[22]

Sibling Sets and Kin Terms. A minor issue in understanding Australian kinship is how the unity of siblings and modulo rules that treat brother and sister as equivalent relate to Dravidian terminology. As in Figure 3, in the generation above ego's, opposite sex siblings are opposite in cross/parallel distinctions relative to ego (see also Figure 2), and spouses are either both parallel (like direct ancestors) or both cross, consistent with moiety and section exogamy.

For relatives below ego's generation, in the canonical (patrisection) Dravidian terminology shown in Figure 2, children "inherit" cross/parallel distinctions in the male line, and the coding by descent is uniformly applied to siblings regardless of sex, while all spouses of siblings are uniformly opposite. Thus the translation of these two logics — sociocentric and egocentric— into their implications for kinship terms also forms a perfect correspondence for lower generations. Although one statement of Dravidian logic can be made from a purely sociocentric perspective (Kay 1967, Kronenfeld 2004) and another from the egocentric or kin-term perspective (Tjon Sie Fat 1998), the two are recodings of the same structure.[23]

Axioms for Alternating Generation Exogamy. Alternate generation moieties, named or not, are universal or nearly so in Indigenous Australia (Dousset 2003:71), either through the patrilines or matrilines (Brendt and Brendt 1983:29) that serve to define them. Parents

[22] While we are trying to keep mathematical complications on the margins of our main argument, the same-generation members in Figure 3 could well be part of a four-section system (modulo 2) or further subdivided into an eight-section system. Another way is to subdivide modulo rules, dividing one of a modulo-2 pair a,b by a further modulo-2 division b′,b″ to make a six section system. This might be consistent with a repetitive marriage series such as a,b′,a,b″, a,b′,a,b″ or with the free variation in whether members of section a marry with b' or b″. An eight-section system might be conceived as a modulo-2 division where each a,b pair is subdivided by a second modulo-2 division.

[23] For sake of completeness in keeping with footnote 15 on how alternate or matrisection Dravidian cross/parallel kin term distinctions differ from those of orthodox (patrisection) Dravidian. As shown in Figure 2, distinctions for relatives below ego's generation are "inherited" in the female rather than the male line (with variants of Dravidian Type A or B in the grandchild generation as in Figure 2).

are always of the same classificatory generation but not necessarily the same genealogical generation. One definition of generation moieties is that siblings and their paternal grandfathers/grandchildren belong to one exogamous group and intermediate generations to the other. The other definition uses female gender lines in defining alternate generations.[24] By figuring generation in a single gender line there is no ambiguity as to how generational depth is reckoned. All these variants are consistent with the definition of generation that follows,[25] and the weakening of each of the above axioms is consistent with a concept of generation appropriate to Australia that foregoes the assumption of closeness in age. Non-exogamous alternating generations extend not only through siblings and half-siblings, but to siblings-in-law, who may vary greatly in age.

Weak Axiom for Generation. Chains of siblings-in-law form a culturally sensitive way to define single Australian classificatory generations without any implication that members of the same generation tend to be of the same age.[26] Multiple siblings and multiple marriages ramify siblings-in-law chains into more complex marriage trees and cycles. Even more complex are the effects of permissible chains that reach to equivalent alternate generations.

Generations based on sibling-in-law chains, as in Figure 3, are not new to anthropology, but have been introduced and analyzed over the last sixty years in ethnographic accounts of the Wikmunkan (McConnel 1939, 1950, 1951), Ambrym (Lane and Lane 1958), Tiwi (Goodale 1959, 1962), Wanindiljaugwa (Rose 1960), Alyawarra (Bell 1993, Denham, McDaniel, Atkins 1979, Denham and White 2005) and other ethnographies and in specifically theoretical works by De Josselin de Jong (1962), Needham (1962, 1971), White (1963), Lévi-Strauss (1970), McKnight (1971), Tjon Sie Fat (1981, 1983), and many others. But these cases and comparative studies have been treated most often as oddities and logical possibilities rather than as keys to understanding Indigenous Australian social organization.

One advantage of our simple Australian-style definition of generations by sibling-in-law chains, generalized to include equivalent alternate generations, is that a marriage rule may be defined with or without a prior rule of reckoning descent. One can even imagine a society in which everyone is connected through sibling-in-law chains, or with multiple marriages propagating dense interconnection, where if parental links were discounted

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[24] In such case the canonical Dravidian "A" kin terminology shown for the generation below ego in Figure 2 changes to an alternate Dravidian terminology in which the cross/parallel terms in ego's and lower generations are inherited matrilineally. In Dravidian "B" this change is extended to the grandchild generation.

[25] Marriages between two paternal divisions and alternating-generation moieties are consistent with four marriage sections, as are marriages between two maternal divisions and alternating-generation moieties. For those persons who have married within their true genealogical generation, the two section systems are consistent. Men will not have women two genealogical generations down from their own (or two up, as in exchange of grandmothers), however, who are section-appropriate for marriage by both patriline and matriline. The 2-off generation marriages are the incompatible elements between patri- vs. matri- section systems and can serve of markers for which system is followed in marriage behavior.

[26] This definition carries no implication that an ego would use distinct kinship terms for those in each of the linked sibling sets such as those in Figure 4. Rather, the relationship distinctions among kin are classificatory. Nor does in imply that the kinship terms are equivalent for alternating sibling sets.

altogether, everyone could be of the same generation given the ability of a single generation to absorb age differences. The Wikmunkan, for example, have a conceptual system for kinship relations that are all contained within a single generation, a concept which works because directed sibling-in-law chains, as in Figure 3, can be extended indefinitely and thus embrace an unlimited array of chronological birth dates. Although Wikmunkan is regarded as controversial because of the "single generation" marriage structure, this structure is consistent with our definition of generation, thus encompassing the Wikmunkan case, and their marriage rules make it permissible to marry within this indefinitely extensible single classificatory generation.

The Wikmunkan are an example of how our implementation of weak modeling principles can cover even the most unusual of cases. It is not illogical, then, for us to propose that weak axioms and models can provide key concepts for better general understanding of Australian kinship, both in common features and its variants. The Wikmunkan case also points to another possible deviation from the European concept of generation: parents and children are, in this case, within the same siblings-in-law generation, which totally violates European conceptions. Marriage to a mother's brother, for example, makes mother and daughter into siblings-in-law belonging to the same siblings-in-law generation. Europeans find this hard to assimilate.

Weakening the Requirement for Endogamy. If Australian kinship logic first defines the modulo-*k* series of exogamous sibling-in-law relations permissible within generations, and then extends the principles of consistency with alternating ancestral generations, we have a generalized and pervasive set of principles capable of self-organization in which locally consistent behaviors produce variants of a systemic global organization. Endogamous closure is not entailed because sibling-in-law chains do not necessarily close into endogamous cycles of marriage: they may be open-ended.[27] That is, while endogamy may take place within a generation or classificatory generation, there is no requirement for prescriptive endogamy within territorial or spatial boundaries. Neither is there a need for territorial or spatial endogamy imposed by alternating generation marriage, which is simply a prohibition against marrying in the same even/odd generation as one's own, or closure of modulo k marriage sets.

Sibling-in-law classificatory generational strings may close on themselves by having a marriage at each end that links the strings to form a cycle of marriages. Whether they do or do not, however, is an empirical question. The graph of all such cyclical chains that have links in common forms the pattern of structural endogamy identified by White (1997) and White and Brudner (1997). Whether structural endogamy closes within a language group or extends outside it is also an empirical question. Even if structurally

[27] Thus, someone related to ego through m female links relative to ego is modulo (m mod 2) = {0, 1}, with 0 indicating the same alternating-generation moiety and 1 the opposite alternating-generation moiety. A 4-section system can be defined by modulo (m mod 2) for female links and modulo (n mod 2) for male links, which is equivalent to alternating generations in male lines. Successive affinal links to sibling sets in a generation defined by a modular rule (s mod k) with s sibling-in-law links are modularized by a divisor of k = 1, 2, 3, 4, or 5. This defines the Wikmunkan one generation system, as well as 4-, 6-, and 8- section systems when crossed by alternating generations.

endogamous closure is within a language group there may still be singular paths of connection between them.

Variability. The definition of modulo systems, like that of sections, allows a great deal of variability, such as two men who (provided they are in the right sections) exchange grandmothers rather than sisters. Marriages within connected genealogical networks governed by section system classificatory rules are extensible both through sibling-in-law chains and alternate generation "jumps" to structurally equivalent genealogical relatives two descent links above or below. Ego's grandfather, for example, could marry a woman in ego's sibling-in-law generation. Among the Alyawarra, for example, we see a clear pattern in which women typically are about 14 years younger than their husbands, but there are a few old men with wives who are about the same age as their husbands and a few others who are about 28 years younger than their husbands (Denham, McDaniel & Atkins, 1979). Thus the model is very flexible in what it includes but very strict in what it excludes.

Prescription Revisited. If a rule of marriage constrains marriage choice to a delimited set of actual genealogical relatives, it is undeniably prescriptive. What if it constrains marriage to a set of classificatory relatives whose genealogical and spatial reach is unconstrained?

Weakening the Prohibition against Implicit Moieties and Sections. We agree with Dousset (2003:71) that alternate generation moieties (and thus sections) can exist without being named. The implicit (modulo *k*) sections we have described for most Australian kinship systems do not depend on section names, but on alternating-generation and sibling-set logics and marriage behavior consistent with these logics. They can also be expanded to 6-section systems by differentiating three equivalence sets for siblings; or to 8-section systems by differentiating four equivalence sets for siblings. The symbols for implicit 4-section designators can be matched to nuclear family roles (a=father, b=mother, c=son, d=daughter) but this is not the case for implicit 6-or 8-sections.

Given unnamed sections, the variability principle also applies to differences in how elements of the section systems are named, and to how kinship terminologies are applied in different contexts (Dousset 2003). The marriage structures of section systems, of course, may be identified as similar or different in their own right.

Unnamed Section Theorem. Alternate generation exogamy through a father-son descent rule (or a mother-daughter rule) plus sibling set modality (pairs, triplets, quadruplets, etc.) entail 4- section and subsection (6-, 8-, 10-, etc.) systems, even if the sections are unnamed. This is a restatement of what has already been explained as modulo rules.

With an alternating generation rule, the theorem follows if chains of sibling-in-law links involve pairings (pairs, triplets, quadruplets) of sibling sets with a repetitive pattern of marriage chains of a given repetition sequence. Then with unilineal inheritance of equivalence set classifications there emerge 4-, 6-, 8-, 10-, etc., section systems.

Self Organization. How is it possible for a society to organize in a way that is consistent with modular or classificatory cognition? Consider again Figure 3, and the possibility of indefinitely long sibling-in-law chains. Names for sections do not have to precede section logic. In a 4-section system every individual of the same gender will have categorizable relations, for example, in same generation and same side, same generation and opposite side, opposite generation same side, and opposite generation opposite side. But, if the system were totally relational in this way, how could marriages between very distant relatives be coordinated so as not to create an inconsistency in how the sections fit together? Clearly, here, names of sections would be useful. But if individuals can identify even one valid path of relatedness —not necessarily through common ancestors but including affinal ties— to determine whether someone is a potential spouse, the answer is simple and definitive: If there is no such path, there is no constraint on marriage, and the new spouse simply assumes the category appropriate to the marriage. A problem arises only when there are two or more kinship paths between distant relatives that stand in contradictory relational categories. Capturing how alternating generation and section logic are constructed socially will help to show the simplicity of these complex phenomena on the ground and the simplicity of cognitive principles that may be involved in classificatory kinship.

Chain Reaction Behavior. Chain reaction provides a means of avoiding contradictions in section systems. Successively intermarried sibling sets, as in Figure 3 for example, will propagate the even/odd alternation of a binary modularity. If everyone acts correctly locally, the occurrence of a distant marriage that would contradict the binary structure would entail a cycle of links in which everyone in the circle has the potential to spot the error in advance (hearing about the potential marriage) and prevent its occurrence.

Enforcing Norms. Modulo-2 rules have the greatest potential for enforcement because every potential deviation from the norms is one that closes a circle in which immediate neighbors to a deviation are present on both sides of the wrong marriage and can collaborate to block its enactment. For enforcement to work there must be advantages to maintaining the norm. The advantages of modulo-2 norms of alternating generations are easy to grasp: elders are prevented from poaching potential wives from adjacent generations, and juniors are prevented from poaching wives from elders.

Marriage Rules, Strategies, and the Game Analogy. Section systems with classificatory logics are *complex rather than prescriptive* because there are many ways to strategize and configure marriages. The pieces in a chess game provide a good analogy: each piece has constraints on *how* it can move, but not on *where* it can move. Modulo-*k* rules of sibling-set marriages have advantages for specifying an ordered flow of spouses between groups: A gives to B, B to C, C to D, D to A, even if A, B, C, D are merely categorical and not concrete groups. Specific groups may lack a demography that enables the indirect "return of the gift" of, say, a wife or daughter, as often conceptualized analytically, but broader categories containing many specific groups have the capacity of satisfying expectations more easily than those that are narrowly defined. Yet, enforcement against violating norms can occur because there will always be neighbors concerned with correct outcomes so that, if the D to A return of the inter-category gift fails to occur, members of C and B

who completed their transactions in this circular flow have an interest and a relation to Ds and to As who could potentially complete the D to A transaction.

Crossing Boundaries. Combining the logic of implicit sections with lack of endogamous closure, it is easy to see how intermarriages across language groups that have implicit 4-section systems can easily be aligned to maintain consistency of marriages. Marriage consistency at the boundary between groups becomes a problem not when there is a single intermarriage but when marriages create cycles cross intergroup boundaries, and the advantages and enforcement incentives are similar to those of same-group marriages. The first marriage sets a limitation on how all subsequent marriages ought to be constituted as between analogous sections. Even when section numbers are incommensurate, such as 4 and 8 or 6 and 8, these problems can be worked out through what Dousset calls the *valeurs* of respective sections on different sides of a border, so that the two section structures are linked in structurally equivalent ways.

Consistency Rule. For sections to be consistent from ego to ego in a network, there must be *no wrong marriages*. It is obvious that *every link* in the kinship network defines relative section membership, starting from ego. If a new marriage is made with someone not linked to ego, that person may be assigned an unambiguous section membership. If a new marriage is made with someone linked to ego by a path that puts them in the "same" even/odd generation this is a wrong marriage and easy to spot by others, thus easy to constrain by enforcement of norms.

The unnamed section theorem offers an alternative to Dousset's idea that section systems diffused with section terminology, although all the Western Desert (and almost every indigenous) society has alternate generation exogamy. Indeed the infrastructure provided by this model underlies named sections and may be seen as a preadaptation for the emergence of explicit, named sections.

Consequence. By means of a simple mathematical model, and an even simpler graphic model that can be "drawn in the sand," so to speak, as in the famous Ambrym case (Lane and Lane 1958) that has become a classic of ethnomathematics, we arrive at an ethnographic conclusion: if alternating generation exogamy plus a rule of descent were virtually universal in Australia, and therefore likely to be old or ancient, then section system *logic* is also *old or ancient*. Different section system terminologies can diffuse easily ―and provide a guide for intermarriage and social integration between local groups that may not recall any prior links― given that marriages within each group, to be consistent with alternating generation exogamy, must also be consistent with an implicit section logic.

There are of course exceptions to the general pattern of alternating generation exogamy, such as the Wikmunkan classificatory kinship system (McConnell 1930), for example, which implies a single endogamous age-skewed classificatory chain of sibling-in-law relations, and marriages within this chain at a certain distance. The exception, however, in this case, fits our weakening of axioms of Australian kinship and conforms to the possibility of open systems of marriage across groups.

Thus the alternating generation exogamy system and its implicit section logic, and the special case of a single endogamous sibling-in-law chain, therefore provide "open networks" for integrating different societies through marriage. A potential is facilitated for finding an appropriate class of spouses within or between societies with the same section logic. And in restricting choice within ones own language group to members of only one section in four, for example, the effect is to push marriages out to link to other societies and form larger networks. Avoidance of wrong marriages is easily adapted to the inter-societal context using only the structural values (*valeurs*) of the sections (Dousset's 2005) and the logic of kin terms within one's egocentric network as a guide. Section membership within egocentric networks assigns and aligns role expectations, perhaps more easily with named than with unnamed sections, but in any case the integration of social networks between groups can be relatively frictionless even in the face of competition and fighting between local groups (which may later cede to close contact, common rituals, and intermarriages).

We suggest that the mathematical *aka* graphical model introduced here is the underlying global theme of Indigenous Australian systems of descent, marriage and kinship,[28] that local systems associated with individual language groups are variations on that theme, and that adjacent local systems can be expected to interdigitate relatively seamlessly despite superficial differences between them. Precisely how they interdigitate is demonstrated in a highly preliminary manner by Brandenstein (1982), more expressly by Dousset (2005), in detail for one case by Denham and White (2005). We return below to the broader problem of detecting and representing the patterns of interdigitation continent-wide.

The Dynamic Model: How it Works

While kinship networks are the focus of our modeling, we do not suppose a static system. Forager paleodemographics may be steady state at a continental level but local demography and social dynamics will show temporal variation associated with the waxing and waning of internal and external "stresses" that impinge on these societies. We suggest that these stresses, and mechanisms for responding to them, constitute the motive force that "powers" the model.

In general, we seek adaptive social and demographic mechanisms that adjust the behavior of the descent, marriage and kinship system as reproductive and environmental stresses wax and wane. Specifically, we seek quantifiable, measurable processes that push the system toward openness when stresses increase, and pull it toward closure when they decrease.

[28] Note that even in the aberrant case of the Wikmunkun, it is not that we merely delete the missing generations in Figure 3 to obtain the single-generation alternative in which alternative generations collapse into one, but that the first and third generations wrap around "slowly" so to speak so that they run through the second generation, forming a single classificatory generation. If this is cored, our model is in that sense more general than those that stop with alternating generations, and includes the Wikmunkan case. We have briefly inspected McConnell's (1930) to check that can be the case, but we have not devoted attention to verifying this conclusion through a network analysis of how each of several marriage rules link up to form a single-generation helix.

Here we re-emphasize our earlier suggestion that one of the main functions of the restrictions placed on marriages in these small scale social networks was to facilitate the integration of regional and continent-wide populations by forcing people to marry outside their own language groups. In modern parlance, we seek to understand how each Indigenous Australian language group created and maintained a "small world" (Watts and Strogatz 1998) in a large space of continent-wide connections.

Stress. We have not attempted to construct a "stress index" that varies over time and incorporates the diverse types of events that the term subsumes, or of the intensities and schedules of these events. Doing so is a worthy undertaking for the future, but here we define the concept intuitively in terms of both demographic (internal) and environmental (external) stress.

"Demographic stress" as we use the expression here refers to stochastic fluctuations in population size and sex ratios. If a group's population size begins to shrink due to random variations in birth rates or random changes in the availability of males and females for marriage and reproduction, the group must respond to that stress or face the high probability of extinction when at relatively small size and/or at a severe point of stress.

"Environmental stress" as we use the term here refers to a) non-recurring events such as the extermination of the Australian megafauna that occurred after human colonization of Australia began 40-60,000 years ago, b) short-term cyclical changes (seasonal and multi-year variations) in temperature and rainfall, and c) long-term climatic changes associated with global warming and cooling. In recent centuries it has included European colonization of the continent, as well as attempts to eliminate or forcibly assimilate the Aboriginal people. From this perspective, the European invasion was not a unique event, but rather was a member of a family of large scale stress-inducing events that may have impinged on Indigenous Australian societies intermittently over many thousands of years. Hence we are concerned with very long term processes where the pace of change most likely is measured in centuries. (Relevant reports based on recent articles in *Science Magazine* and similar sources are easily accessible at the ScienceDaily website. A small sample of many relevant ScienceDaily reports appears in chronological order, with their URLs, under References Cited.)

The Marriage Helix. Here we provide a general introduction to a double helix model of Indigenous Australian descent, marriage and kinship, and expand upon it below. The helical model introduced here is a local manifestation of the global model introduced in Figure 3, and articulates with it at all points. It exemplifies those cases where the age-skewing shown in Figure 3 are in full play, although age-skewing may vary by degree and by the extent to which the relative stability of age-skewing over time has worked its way into alteration of conventional marriage choices and kinship terminology.

Here and in the remainder of the paper, we are fully aware that there are neither 1-to-1 correspondences among ideology, genealogy and behavior, nor are there unidirectional causal arrows connecting these "levels" with each other. At the same time we are equally aware that these three "levels" are not free-standing, independent entities. The argument

that they are often very inconsistent (e.g., Read 2007, 2008, personal communication) is counterbalanced by Houseman and White (1998) who demonstrate that cognition, biology and behavior are highly convergent in systems with the sidedness distinction, including Indo- and Austro-Dravidian systems. We do not yet have procedures for precisely measuring relatedness among these three levels within any society, however.

On the basis of works such as Brandenstein (1982), Dousset (2005), Denham, McDaniel and Atkins (1979), Denham and White (2005), McConvell and Alpher (2002) and Houseman and White (1998), we opt for convergence rather than divergence among these levels, at least among Indigenous Australian societies whose kinship axioms have been relaxed in ways that we introduce below.

As Denham, McDaniel and Atkins (1979) showed for the Alyawarra, the genealogical structure of actual marriages and of the distribution of kinship terms within a local kinship system may assume the simple stratified form in Figure 4 that early ethnographers such as Radcliffe-Brown (1931) and his followers used throughout the 20th century. However, the age bias that underlies the global mathematical model introduced above has major implications for the structure of local and regional manifestations of that model.

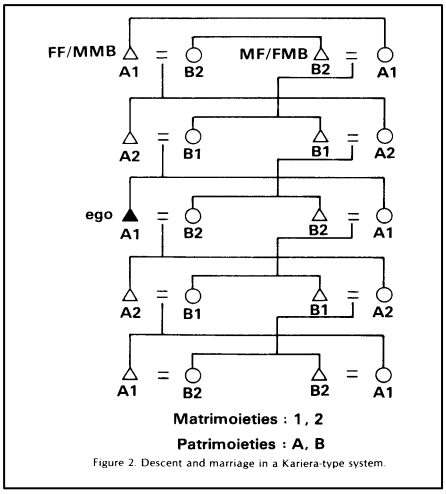

Figure 4. Closed stratified model

As the average of age-skews increases, within a locality, perhaps in response to internal and external stresses (but in any case departing increasingly from the equilibrium point at which there is no age skew), the system eventually reaches a phase boundary where horizontal closure of each stratum through endogamous sibling exchange becomes impossible, and the structure transforms itself in a single step from the stratified form in Figure 4 to the closed age skewed double helix form in Figure 5.

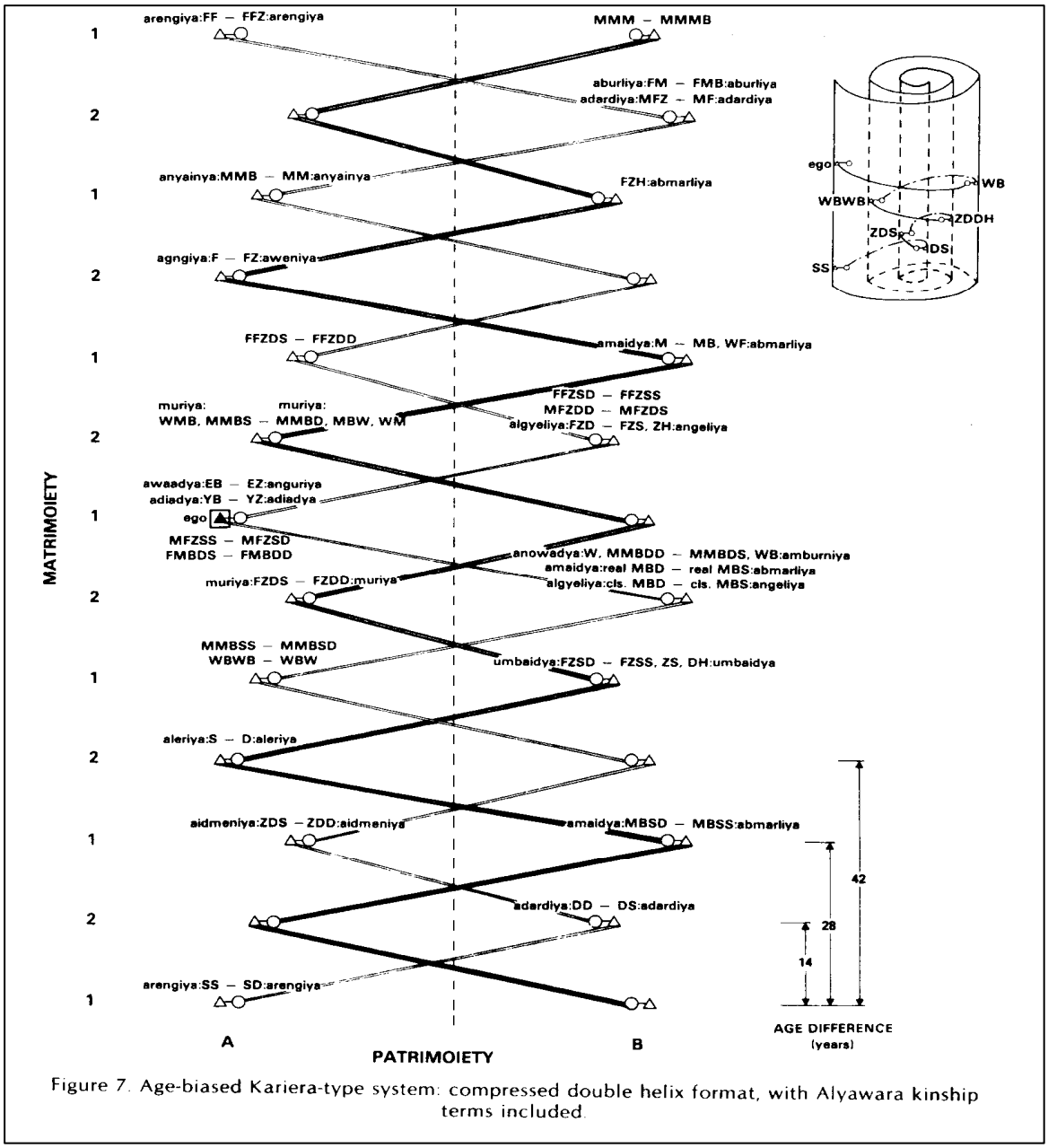

Figure 7. Age-biased Kariera-type system: compressed double helix format, with Alyawara kinship terms included.

Figure 5. Closed helical model

Our hypothesis is that as internal and external stresses increase further, the slope of the age skew will increase as well until marriage within the closed system begins to fail, whereupon the structure transforms itself again from closed helix to open helix as in Figure 6, thereby more easily accommodating marriages across language group boundaries in accordance with the global mathematical model. The open helix does not necessitate exogamous marriages but can accommodate them easily.

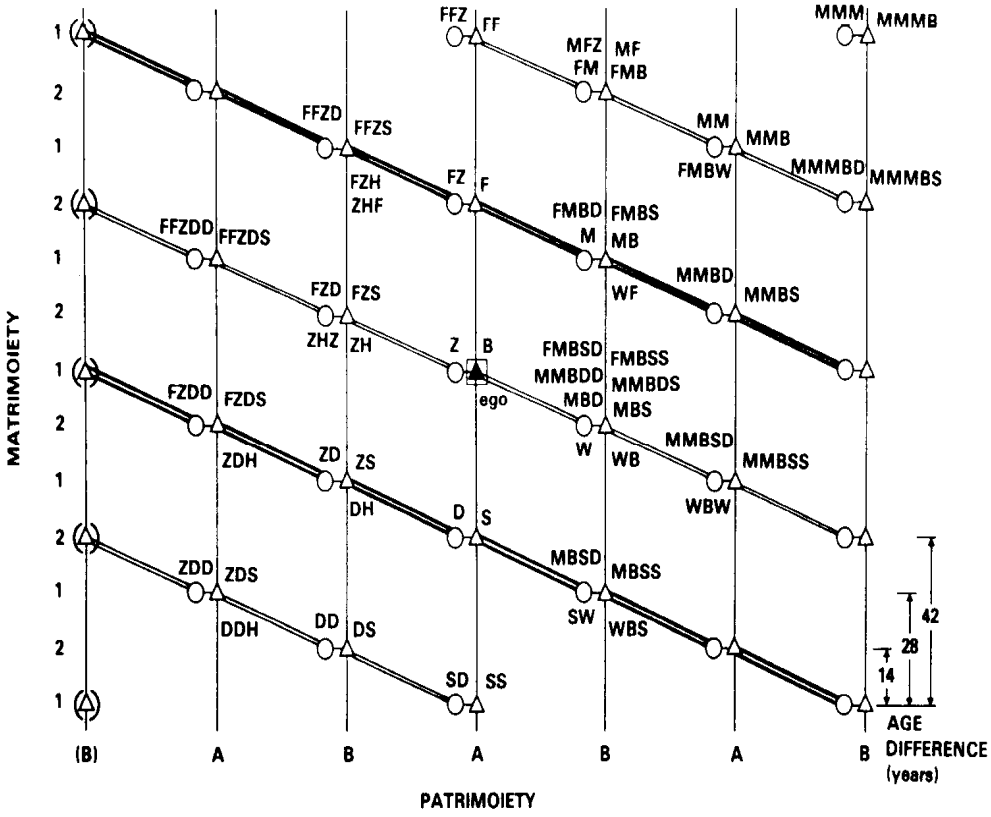

Figure 6. Age-biased Kariera-type system: "open" format.

Figure 6. Open helical model

If internal and external stresses decline, the open structure can ratchet back down to the closed helix and ultimately to the default stratified form. Hence the marriage helix is not just a structural feature of the model. Our hypothesis is that it also functions as a stress indicator.

The transformation of the simple stratified structure (no age-skew) into the helical structure occurs by virtue of descendants of a common ancestor down **m** generations in a matriline marrying spouses that are *equivalent in the classificatory system* to descendants **p** generations down in the patriline. Generally, in such a model, $\mathbf{m} \geq \mathbf{p}$, and operate as integer numbers, Tjon Sie Fat (1983) was able to identify the kinship models denumerable within six traditional generations that are produced by helical assumptions about endogamous closure in prescriptive marriage systems.

Denham and White (2005) compared statistics on 114 actual marriages with the marriage classes defined by Denham, McDaniel and Atkins's (1979) classificatory helical model

(see Figure 8 below), and found substantial fit, but also substantial deviation.[29] In that article we showed that there were no married couples whose ancestries could be determined at a sufficient depth to substantiate actual genealogical connections that fit the model, rather than classificatory fit. We argued for the "open helix" of Figure 6 as the more general model, and that marriages between blood or affinal and classificatory relatives could be made that could close the helix at different points in the same or in quite different ways. That is, different rules that are congruent with the classificatory logic of the helix (and even many different helices strung together consistent with that logic) could all operate in parallel. Further, it is a single model of how a kinship system could operate as an algebra of equivalence sets and relations that can reach across indefinitely extended chains of sibling-in-law and parentage relations and an unbounded population in a way that does not entail local endogamy. Most importantly, notice that algebraic closure on equivalence sets and relations *does not* entail endogamy or population closure. This is a mathematical feature of Australian kinship that is rarely if every fully understood either by ethnographers (here we may be mistaken as we have not searched for exceptions) or by those constructing algebraic kinship models.

Age-skewed generations have different generational slopes as roughly indicated by the oblique lines in Figure 3. These slopes are roughly a function of the average age of marriage of men and women, with the difference of age being also the average number of years between a brother's and a sisters' marriage.

We suggest that the relative slope of the helix in Figure 3, like those in 5 and 6, is an index of environmental and demographic stress. The slope, based on mean age difference between husbands and wives, reflects the demand for wives. If a shallow or nonexistent slope indicates a local balance between supply and demand, a positive slope might indicate an imbalance due to a shortage of unmarried marriageable women, and a negative slope an excess number of women within the system. Hence we suggest the hypothesis that the slope of the helix roughly indexes demographic and environmental stress. We discuss this issue below in conjunction with polygyny.

Marriage Rules. We envisage the marriage helix and the network of interconnected "diagonal" generations embodied in the mathematical model as lying at the foundation of the system we are building. Although the moiety / section / subsection / marriage class / skin systems that metaphorically lie atop that foundation ―as schematized in variant Figures 4-6, but is shown empirically by Denham and White (2005) as actual network graphs for the Alyawarra― embody the option of altering their structure "up" or "down" from 2 to 4 to 6 to 8 to 10 classes (Cooper 1983), all of which are fully compatible with the structure of the foundation but these variants have different implications as regards marrying close or distant kin. The transition from 4 sections to 8 subsections, for example, corresponds to a shift from preferential MBD marriage to preferential MMBDD marriage, which pushes marriages outward. That outward orientation intensifies when the marriage preference shifts further from "proper" to "classificatory" kin.

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[29] For a complete discussion of the statistical data and computations that yielded Figures 5, 6 and 8, see Denham, McDaniel and Atkins (1979). For detailed discussions of field methods, data collection procedures and the network analysis that generated Figure 8, see Denham and White (2005).

The adjustments suggested here may be complex. For example, the Alyawarra in 1971 had a 4-section system that was virtually identical with that of the Eastern Aranda, combined with a kinship terminology that was virtually identical with the 8-subsection form used by the Northern Aranda. Denham recorded some marriages with MBD in accordance with the 4-section structure, and some with MMBDD in accordance with the 8-subsection structure. Was the system a static hybrid in a field of discrete and isolated systems, or was it in transition in the dynamic field provided by the model proposed here? We suggest that it was a system in transition, not necessarily in transition from Northern Aranda to Eastern Aranda or vice versa, but rather in an "inward" or "outward" transition between 4 sections and 8 subsections with a corresponding shift in kinship terms that fit the new condition. Also, shifts into and out of 6-class systems from 4- and 8-class systems are entirely possible. For example, in their paper on Ambrym kinship, Lane and Lane (1958:132) argued that a historical transition from 4 sections to 6 sections, with a concomitant change from sibling exchange to MBD marriage, expands the scope of the incest prohibition.

Omaha Kinship Terms. We envisage kinship terminologies as resting atop the mathematical relations and the 2-, 4-, 6-, 8-, 10-class system that together constitute the conceptual foundations of the proposed model. We believe, with McConvell and Alpher (2002), that social rules restricting marriage choices locally have the effect of forcing more mating or marriage between groups and thus forcing genes and reproduction into a more global population spread, thereby reducing the chances of local extinctions. This would explain why the variant kin-term usages that we see among the Alyawarra and elsewhere in Australia are of the Omaha variety in which the number of *proscriptions* is increased, spreading marriage choices and gene flow even more widely in Central Australia (Denham, McDaniel, Atkins 1979; Denham and White 2005) and in the North (McConvell and Alpher 2002). That is, if the seemingly prescriptive category of potential wife (for example, MBD, the marriageable category) is changed through the mandatory or optional use of Omaha skewing to the term for mother so as to forbid marriage with a woman of this designation, then the dispersion of alliances (McConvell and Alpher 2002:174) is enhanced. This is precisely the pattern of variant kin term usage that we see. Perhaps the patterns that we see were confined to Indigenous Australians but perhaps not (Lounsbury 1964b).

We suspect that age skewing and Omaha skewing are two faces of the same thing but have not yet found unambiguous evidence to support this hunch: the logic of extending Omaha categories so as to render otherwise marriageable relatives and push marriage away from close relatives would require close inspection of a large sample of cases.

Polygyny. Polygyny is common among Indigenous Australians, and we suggest that its frequency is directly related to the slope of the generational helix, serving as another demographic indicator of stress just as we think the slope of the helix does. Also, as noted above, Saether et al. (2004) argue that estimated time to population extinction is shorter for monogamous than for polygynous mating systems, which they qualify as a finding that holds particularly if density regulation acts only on females than rather on the total population, so there is a complex cluster of variables to be examined here. But polygyny

as a stress index is most intelligible if we consider it from a woman's perspective, and within an ecologically and linguistically defined subset of Indigenous Australian societies, and the implications of this perspective need fuller examination.

Women living under conditions of increasing internal and external stress may select as a husband a well-established older man who already has wives and children rather than a young man who has not established a track record in either siring or supporting children. Among the Alyawarra, the *mothers* of a cohort of unmarried young women in a specific section decide precisely who those young women will marry when it is time for them to do so. When women's mothers make the decision, it is likely that they will select for long-term productivity rather than short-term bliss. Hence in this scenario, as stress increases the average age at which women first conceive remains roughly constant at the onset of puberty, the average age at which men marry increases as younger men are marginalized and the scales tip inevitably toward polygyny. Thus polygyny in this context is not a reward but rather is a burden (perhaps compensated by other demands) imposed upon older men by women who make the marriage decisions. It carries increased responsibilities for providing resources and protection for younger women and their children, especially during periods of increasing stress. In sum, as stress increases, women's preferences for older men with good track records marginalize young men who, finding no wives within their own language group, either marry out or die out.[30] Thus, density regulation may operate more intensively on men. Hence the frequency of polygyny functions as a stress index like the slope of the helix, and contributes in a manner that might be consistent with determining the slope of the helix.

Keene (2002:150), however, challenges this scenario when he says that Indigenous Australian societies with "... high to very high polygyny appear to have been restricted to the coastal regions and large habitable islands off the north coast". Generally speaking these coastal areas are ecologically richer than the arid zone that dominates the interior of Australia. Hence, Keene argues that the highest rates of polygyny appear in places where stress should be *low*, while we might have predicted the opposite, except that here there might again be heavier density regulation on males competing for wives than on females.

White (1988), using Murdock and White's (1969) Statistical Cross-Cultural Sample, concluded that there are two different types of polygyny, or at the very least two ends of a continuum along which most cases of polygyny fall. Here we call the two forms of polygyny "female power enhancing" and "male power enhancing." At the female power extreme in the worldwide sample is a cluster of societies in which polygynous men have only a few wives, as Keene describes for Australia's arid zone. These small groups of co-wives tend to be sisters who marry their common husband as they reach maturity. Their numbers are limited by the size of the sibling set. Intragroup cooperation dominates over competition, and these groups of co-wives function primarily to enhance their own success as co-parents of all their children, and as co-workers within the household. At the male power extreme in the worldwide sample is a cluster in which polygynous men have

[30] Adulterous and homosexual relationships might be entertaining for marginalized males, but we see no way in which they would have a significant bearing on the much more serious business of descent, marriage and kinship that applies to the society as a whole.

many wives, as Keene describes for coastal Australia. Generally speaking these co-wives form a disparate group in terms of kin relations and means of acquisition (purchase, capture, etc.), intragroup competition dominates over cooperation, and groups of co-wives function primarily to enhance the power, wealth and prestige of their husband.

Thus we find two interesting sets of large-scale correlations concerning polygyny among Indigenous Australians. On the one hand, female power-enhancing polygyny (White 1988) predominates in the arid zone (Keene 2002), which is characterized by the Pama-Nyungan language group, Dravidian kinship, and Omaha skewing (McConvell and Alpher 2002). On the other hand, male power-enhancing polygyny (White 1988) predominates on the richer north coast (Keene 2002), which is characterized by the non-Pama-Nyungan language group, Iroquois kinship, and Crow skewing (McConvell and Alpher 2002).

We suggest that our interpretation of polygyny works well in Australia's huge arid zone characterized by Pama-Nyungan languages, Dravidian kinship, Omaha skewing, and possibly higher rates of sororal polygyny, but despite gender differences in density regulation might still be harder to apply to the smaller but richer habitats characterized by non-Pama-Nyungan languages, Iroquois kinship and Crow skewing. Not having fully investigated the confluences of these factors we do not understand their effects. One hypothesis might be that Crow proscriptions against repeating marriages into the lineages that father is married into combine with nonsororal polygyny to create a further tendency toward spreading marriages more widely.

Genetics and Infanticide. Indigenous Australian populations that are reproductively closed in terms of kinship are by definition genetically closed as well. Not only would closure increase the likelihood of extinction of these groups due to stochastic variations in the number and sexes of potential spouses, but also it would increase the potential negative impacts of inbreeding depression and related genetic problems (Bijlsma, Bundgaard, Boerema, 2000; Brook, Tonkyn, O'Grady, Frankham, 2002; Charlesworth, Charlesworth, 1987; Morton, Crow, Muller 1956; Morton, Imaizumi, Harris, 1971; Tanaka, 1997, 2000).

If static closed population models were accurate, we should predict that 40,000 to 60,000 years of isolation would have yielded phenotypic differences among Indigenous Australian language groups ―and their languages― equivalent to phenotypic differences among human populations worldwide. Furthermore, static closed populations with prescriptive first-cousin marriage would entail the highest frequency of autosomal recessive disorders outside of strictly incestuous relations, yielding potentially high levels of inbreeding depression and correspondingly elevated mortality rates. We see little or no evidence to support these predictions.

But what would happen if the marriage regime were free to oscillate between full reproductive closure and low levels of closure as we propose here?

When environmental and demographic stresses were minimal and a society displayed a closed marriage regime based on inbreeding, inbreeding depression would intensify and keep the population under control with Malthusian limits relaxed. Conversely, when stresses were maximal and the society displayed an open regime based on out-breeding, inbreeding depression would diminish and allow the population to expand as much as it could when Malthusian limits were most intense. Thus by *improving* the "genetic quality" of babies born under conditions of greatest stress, the system would counteract the effect of increased infant mortality under poor conditions, and by *reducing* the "genetic quality" of babies born under good conditions, it would keep population numbers down when otherwise they would be likely to increase explosively as Malthus predicted in 1798.

Genetic wastage would have been virtually invisible among Indigenous Australians when inbreeding depression occurred, for the resulting increase in infant mortality would have been masked by whatever "normal diseases" attacked these especially vulnerable babies. A doctor working with a closed Aboriginal population at just the right time might spot the genetic disorders, but it would be absolutely impossible to obtain information about them by interviewing Aboriginal informants after the fact.

The natural process outlined here by which the infant mortality rate increases and decreases under varying intensities of stress might yield results similar to infanticide as the population control mechanism advocated by Birdsell (1968) but the mechanism is radically different. Caldwell (2006) points out that there is almost no data concerning infanticide among hunter-gatherers. That which is cited whenever the subject arises is highly questionable on several grounds and the better quality data for Indigenous Australians points only toward rare infanticide during acute famines. As one of many examples, Rose (1960) reports a high male:female sex ratio from Groote Eylandt due not to preferential female infanticide, but to his own inability as a male to see, interview and count females in a sexually segregated society. We suspect that infanticide as a systematic population control mechanism among Indigenous Australians may be a myth, but natural fluctuations in infant mortality rates under varying degrees of stress probably contributed significantly to maintaining long term population stability.

We view the emergence of social complexity from simplicity in an empirical manner and reject reductionist explanations which argue that social structure is *nothing but* cognition or rules or behavior. We suggest that the demographic and behavioral responses to stress described here are not imposed teleologically by creative Aboriginal social engineers, but rather emerge pragmatically by means of Darwinian natural selection and trial and error processes of adaptation, and enter cognitive and verbal domains by means of insightful Aboriginal discovery. So we postulate a complex network of feedback relations among demography, genetics and environment; descent and marriage; explicit and implicit moieties, sections and subsections; and a continent-wide network of interconnected kinship logics and terminologies. We focus on the emergence of complex interactional patterns that give rise to a corresponding set of cognitive and verbal patterns that then yield feedback that further shapes the interactions.

Assembling a Dynamic Model. Here we provide an integrated mechanism for coping not just with the "background stress" that characterizes the Australian habitat at all times, but also with *changes* in levels of stress. We aim for a synthesis that pulls the pieces together and sets the system in motion.

First, our mathematical model argues that moieties, sections and subsections, both implicit and explicit, may have and probably did emerge early in Indigenous Australian history as a mechanism that integrates and stabilizes the demography of small groups. Hence we suggest that the mathematical model is a continent-wide foundational structure of great antiquity.

Second, the rapid diffusion of section and subsection terms and Omaha kinship terms on top of the structure that is explicit or implicit in the generational moieties and descent lines provides strong evidence for the existence of a continent-wide network of local and regional networks embodying the features built into our model.

Third, with these structures in existence, they had the potential to respond to changes in stress levels. We suggest the following scenario as in Figure 7:

a) The lowest level of demographic and environmental stress is represented in Figure 4 and the "Low" column of Figure 7. It is characterized by a maximal reduction in H>W (husband-wife) age differences, a downward shift in the number of classes, a corresponding acceptance of reproductive closure, and a reduction in or disappearance of Omaha skewing. At this "lower limit" the descent, marriage and kinship system "relaxes" to show flat stratification, becoming symmetrical, closed, bounded, isolated and minimal in every way. Marrying across language boundaries is not prohibited, but there is little or no motivation in this scenario to seek mates beyond one's own boundaries. Polygyny becomes less frequent and inbreeding depression become more intense. The situation described here corresponds to the superficial view of Aboriginal kinship that early ethnographers such as Radcliffe-Brown (1931) perceived but never penetrated. Due to the serious environmental stresses that characterize much of Australia under the best of conditions, this configuration probably is unlikely in the real world of today, but is the theoretical minimum.

b) The break from stratified to helical structure represented by Figure 5, which occurs due to an increase in mean H>W age differences, is associated with an increase in the frequency of polygyny, as in the "Mod" column of Figure 7. Thus emerges the closed double helix model proposed by John R. Atkins (Denham, McDaniel and Atkins 1979). Demographic and environmental properties are suboptimal but are not critical. The number of classes increases and marriage rules begin to push people outward from close kin to distant kin. While the frequency of polygyny and the slope of the helix increase, the helix itself remains self-contained, bounded, closed and isolated. Reaching out to exchange with other similar systems is possible but it is not yet required for the survival of the system. Perhaps this was a transitional phase historically, but Bell (1993) independently confirms that a system of two helical generations, corresponding precisely

to Atkins' double helix model, informed the world view of the Alyawarra at Warrabri Settlement in the late 1970s.

c) As conditions further deteriorate across the desert, say with the extinction of the megafauna or long term climatic changes, the helices "unfold" horizontally to assume an "open" configuration that is represented in Figure 6 and the "High" column of Figure 7, thereby facilitating the exchange of mates between neighboring groups. Likewise, we see further increases in polygyny, the number of marriage classes however defined, and the frequency of Omaha kinship term usage, all of which direct marriages outward rather than inward. And we see a decline in the frequency of genetic disabilities among children.

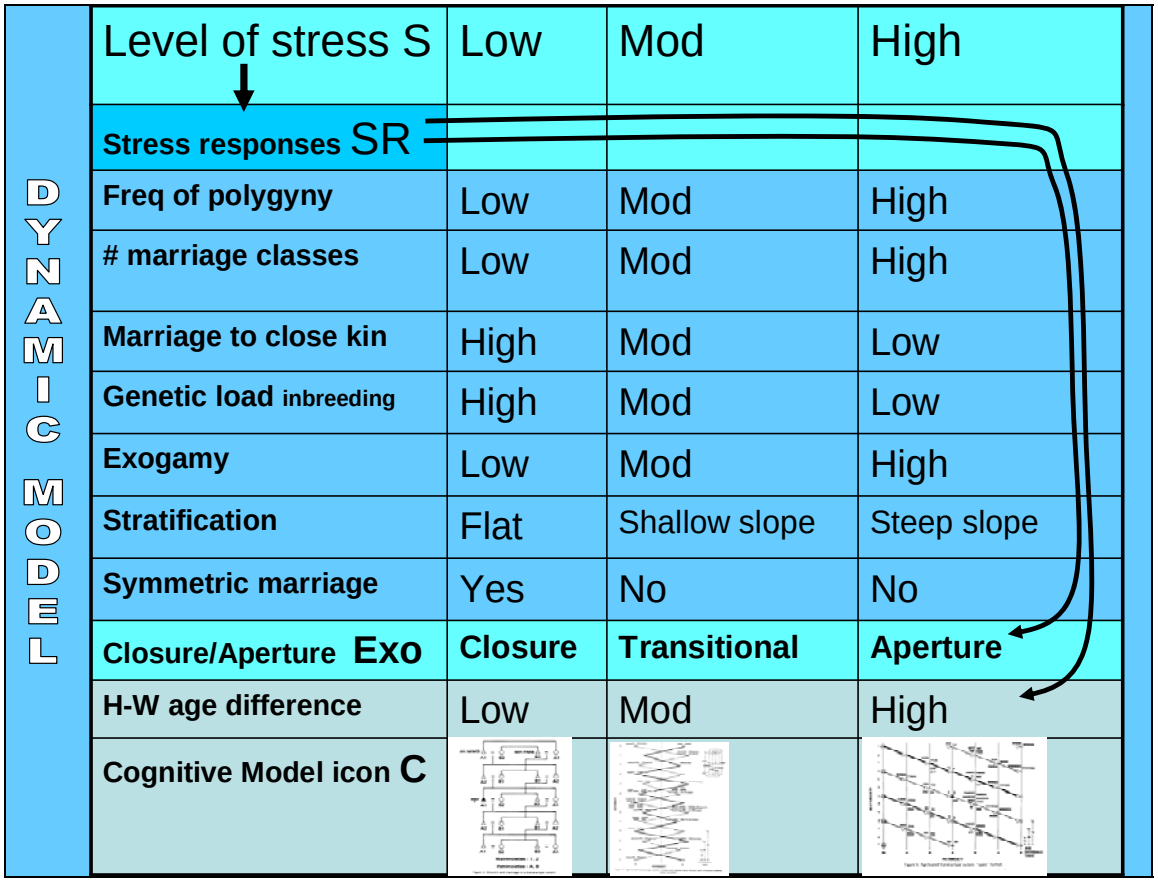

Figure 7. Key relationships in our dynamic model of Indigenous Australian descent, marriage and kinship. See explanations in the accompanying text.

d) If conditions improve, the motivation to reach out diminishes. At least in principle the helices could disengage from their neighbors and fold in upon themselves again. The number of classes, the frequency of polygyny, and the frequency of Omaha kinship term usage would decline, and the frequency of genetic disabilities among children would increase. The actual frequency and extent to which societies might "fold inward" under the chronically stressful conditions that characterize the Central Australian environment is a different question.

Our argument runs directly counter to important parts of Read and LeBlanc's (2003) model of "Population Growth, Carrying Capacity and Conflict" among hunter-gather societies. Generally speaking, we are concerned that their model contains at least the following three flaws that make it largely inapplicable to Indigenous Australian societies.

Co-residential group compositions above the household level. Corporate groups for resource access / ownership are central features of their Model 4— Resource Access / Ownership Unit. Here we focus on "corporate groups" as Read and LeBlanc (2003) use the expression. In most if not all Indigenous Australian societies, corporate groups for resource access / ownership simply do not exist. Patrilineal descent groups do indeed have ties to land and resources, but they function primarily in the domains of marriage and the maintenance of the universe, and have nothing to do with resource access or ownership. Radcliffe-Brown's (1931and earlier) closed patrilineal/patrilocal hordes have been dismissed (Hiatt 1996:25) as figments of his imagination. Subsequent academic attempts to define co-residential groups above the household level have revealed a great deal of openness, flexibility and unpredictability in their structure and composition. Repeated attempts by the Australian Government since 1970 to carefully delineate these groups have consistently failed. Unsuccessful efforts to understand the composition of these groups suggest that we should weaken our assumptions to accept friendship— instead of or in addition to kinship —as a principle underlying their organization. In other words, just as we have argued for actual or potential openness of conceptual groups, we argue against closure and *for openness* of these co-residential groups.

Land ownership. Here we focus on "resource access / ownership" as Read and LeBlanc (2003) use the expression. One of the most contentious issues confronting the Australian government today in its relations with Indigenous Australians is that of Aboriginal land ownership. Hiatt (1996:29) argues —and implicitly Read and LeBlanc (2003) as well— that European law defines land ownership in terms of a right to alienate (sell, give away) the land, and a right to exclusive use and enjoyment of the land. Hiatt (1996:29) correctly notes the ethnocentric logic embodied in these notions, and asserts that among Indigenous Australians a right to alienate the land is unthinkable, and a right to exclusive use of it is regarded as indecent. From an ethnocentric British legal perspective, the Aboriginal people do not and have never owned the land or its resources, but among Indigenous Australians, the inability to conceive of alienating the land or of prohibiting anybody from using its resources is the very foundation of all land responsibilities.

Discussion of Indigenous Australian land and resource ownership in a European sense is meaningless however you phrase it. The people do not "own" the land; rather they "belong to" the land and are responsible for the sacred sites and resources located on it. "Responsibility for" is not equivalent to "ownership of". By trying to force Aboriginal relationships to land into a European mold that is simply irrelevant, the battle about Aboriginal land ownership has raged for 240+ years.

Indigenous Australians "take care" of the land and its resources in perpetuity. They cannot sell it or give it away, and they cannot restrict access to some of their people and permit access to others. The Law of the Dreamtime specifies that they shall take care of it

forever, for the good of all, and in return the land and its resources will take care of them forever.

Competition or cooperation. Intergroup competition is the central feature of Read and LeBlanc's (2003) Model 2— Intergroup Competition. They accept the common sense argument that as availability of resources increases, competition for them diminishes, whereas when availability diminishes through ecological degradation or population growth, the likelihood of intergroup competition (possibly conflict) increases. This leads one to predict a great deal of intergroup competition or conflict over land and resources throughout Australia. However, data on intergroup competition for land and resources is largely absent from the literature on Indigenous Australians even though they live in one of the most challenging habitats on Earth.

We have argued (above) that when the availability of resources is high, Indigenous Australian populations are free to "close in on themselves" and become increasingly self-sufficient (which agrees with Read and LeBlanc), whereas when the availability of resources diminishes, populations are more likely to "open up" and reach out to others for mates and other resources— to engage in cooperation rather than competition—, which contradicts Read and LeBlanc. The Australian "small world" depended upon a degree of actual or potential openness that Read and LeBlanc do not accommodate.

Our position then is that corporate groups, land/resource ownership and competition, in the senses in which Read and LeBlanc (2003) construct their model(s), simply do not exist among Indigenous Australians. Instead, we postulate open and highly flexible co-residential groups, a complete absence of ownership in any English-language sense of that term, and the presence of cooperation instead of competition (in spite of considerable interpersonal fighting), especially when the going gets tough.

Read and LeBlanc (2003) deal with a universe based on closure and exclusiveness; we deal with one based on openness and inclusiveness.

Thus we do not envisage a paleodemographic forager steady state system that just stays put, static, doing the same thing for all of eternity come what may. Rather, we posit a large-scale system in dynamic equilibrium responding to internal and external stresses over very long periods, with excesses here compensating for deficiencies there such that NRR for most or all groups remains more-or-less constant even during periods of elevated stress. It is an integrated set of mechanisms, based on openness instead of closure, which produces measurable adjustments to naturally occurring changes in stress levels, thereby enhancing long term survival continent-wide.

The Three-Level Suite: How to Test It

We envisage a three-level suite of models. The bottom level is the mathematical foundation that manifests itself in a global network of sibling-in-law chains right across Australia; local helical structures are embedded in this global pattern. The middle level

holds the adaptive mechanisms in the form of regional sociodemographic processes that maintain population stability. At the top level we find a cognitive superstructure in which traditional anthropological models of descent, marriage and kinship among individual language groups are embedded.

How well do these levels work, separately and together? This is an intrinsically statistical question concerning events for which statistics are exceedingly rare.

Testing Locally. At various points above, we introduced data that are compatible or incompatible with our argument. Here we build on those data by introducing even more of it.

Goodale (1959, 1962) discovered that the effects of age or other differences between spouses increases the likelihood of matrilateral over patrilateral marriage (see Hammel's famous 1976 paper on that subject), and thus open system marriages and those consistent with consecutive kin terms can more easily articulate to marriages with members of other groups.

The famous "discussions" recorded in various groups like the Aranda as to whether to move from 4 to 8 sections (Spencer and Gillen 1899:421-22), and the famous Ambrym diagrams (Lane and Lane 1958) reflect actual decisions about whether to change the rules to adjust ―depending on the conditions at the time and factors in the discussions― or to accept an innovation from outside, like Dousset's diffusion of sections. These would show that some of these adjustments are conscious, some are decisions at the group-level and others at the individual level, and others are unconscious or simply behavioral variants that have a positive selection value.

A direct quantitative test of inter-linkages between language groups appears in Figure 8, derived from Denham and White (2005). It depicts the genealogical and marriage network in Denham's Alyawarra data (Denham 1971/2007). It contains all 377 individuals (198 males and 179 females), all 114 of the known marriages, all 323 links from children to their fathers and all 275 links from children to their mothers. The sizes of the nodes, except for the very smallest that represent missing data, are proportional to age of each individual, in 5-year age cohorts, e.g., 0-4, 5-9, up to 90-94 except that the smallest sizes of nodes represent missing data on age (most commonly, deceased but remembered ancestors).

The Figure is organized into classificatory patrilines K'-Q' determined by a simple algorithm for matching genealogical and inter-lineage marriage relationships to the open helical model in Figure 6. The algorithm begins by taking the pair of lineages with the greatest number of intermarriages, and placing the lineage that predominates as wife-takers to the left of the one that predominates as wife-givers. The vertical alignment of individuals in generational cohorts is then arranged so that the age-cohorts match across lineages. This alignment is usually not horizontal, but staggered.

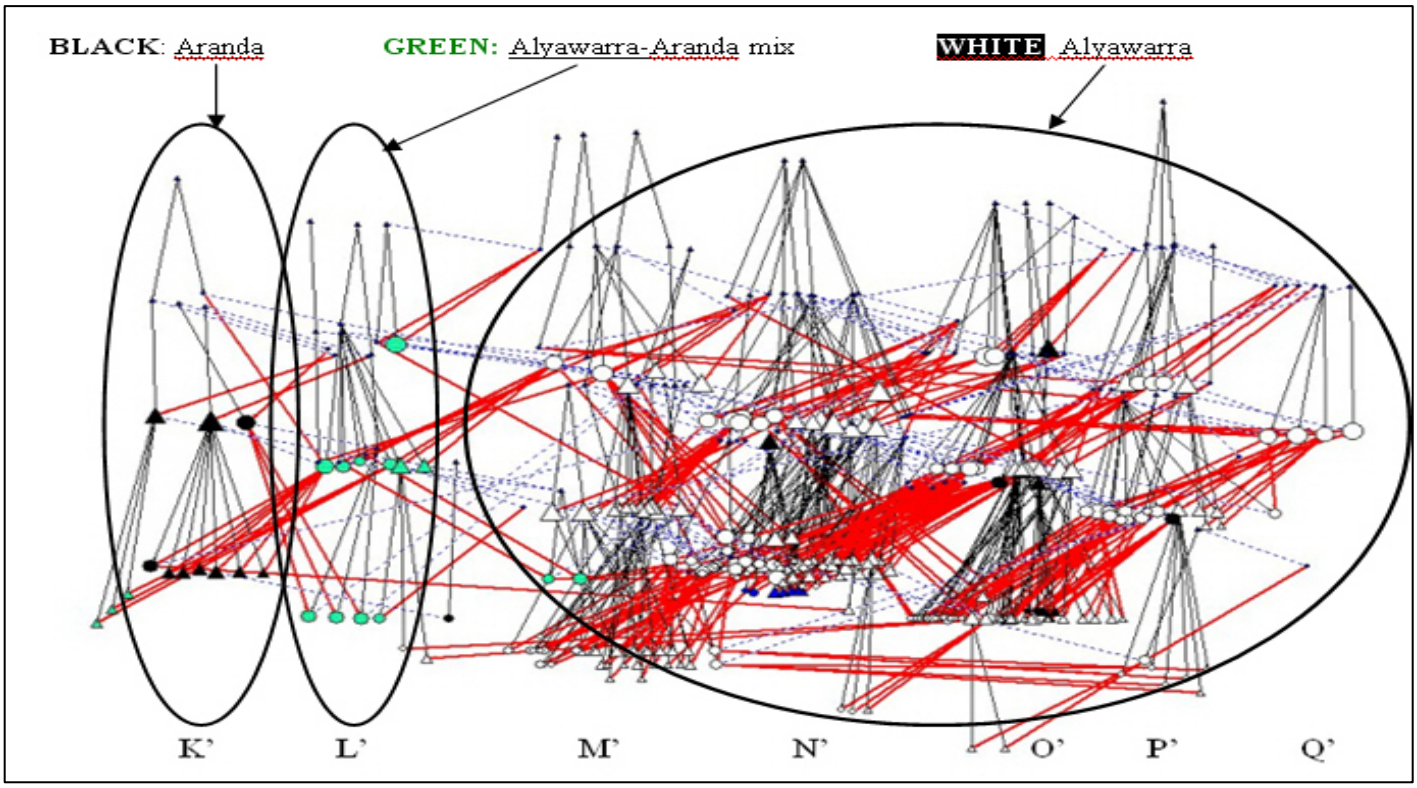

Figure 8. Network patterns in Denham's (1971/2007) Alyawarra marriage data. Network generated using Pajek network analysis software (Batagelj & Mrvar 1998; de Nooy, Mrvar & Batagelj 2005).

Key to Symbols

People	Marriage and descent linkages	Language group memberships
O = females	Dotted blue lines = Marriage links	White = Alyawarra
Δ = males	Solid red lines = Mother-child links	Green = Alyawarra-Aranda
	Solid black lines = Father-child links	Black = Aranda

For vertical groupings K'-Q', see explanations in the accompanying text.

The two seed lineages in this figure are M and N, out of a total of 54 lineages defined by patrilineal descent from a common (known) apical ancestor. Next, all other lineages that are predominantly wife-givers to M are added to a superclass of lineages that contains N, and now designated as a classificatory patriline, N'. Next, all other lineages that are predominantly wife-takers from lineages in N' are added to a new classificatory patriline, M', that contains M. This process is now repeated to identify potential classificatory patrilines. To the right of N' are added successive wife-givers O', P', Q', etc., until no more can be added. To the left of M' are added successive wife-takers L', K', J', etc., until no more can be added. At each stage the relative age cohorts are adjusted so that they are uniform across the diagram in the sense that the average age of each cohort for each classificatory patriline follows a regular progression.

Alternating patrilineages K', M', O' and Q' belong to the Kamara and Burla sections, while L', N', and P' belong to Pityara and Ngwariya (to improve clarity, section membership is omitted from this version of the figure: for details, see Denham and White 2005). Marriages are perfectly sided in the sense they all occur between two distinct sets of patrilines, and these sets correspond to the Kamara-Burla versus the Pityara-Ngwariya classificatory patrilines. Since Pityara and Ngwariya are in the same patrilines, their side of the bipartite marriage system forms an unnamed patrimoiety that intermarries with Kamara and Burla. In addition, however, the distinct sets of matrilines that belong to the Ngwariya-Burla pair of sections are on opposite sides of the bipartite marriage system as opposed to those that belong to Pityara and Kamara. These are standard features of Australian descent, marriage and kinship systems. (See also Houseman 1997, Houseman and White 1998, Denham and White 2002, 2005.)

The following features stand out in this analysis:

- 5 classificatory Alyawarra patrilines, the number determined empirically
- Seamless links from Alyawarra to part-Aranda and Aranda patrilines
- 98% of the marriages are consistent with "correct" section memberships
- 74% are consistent with the 14 year mean age skew
- Sororal polygyny is pervasive
- 15% of the terms for MBD/MBS show an Omaha skew (omitted for clarity in Figure 8)

We see, then, that marriages among the Alyawarra correspond very closely to the age-biased open helical model, and that marriages between the Alyawarra and neighboring groups such as the Aranda not only may occur but in this case were both extremely frequent and extremely coherent in terms of the open helix model. Inter-societal linkages between the Alyawarra and Aranda are seamlessly integrated by consistent section rules, with a virtual absence of "wrong" marriages. These patterns correspond precisely with predictions from the open helical model in Figure 7. One can imagine these open helices as strings of marriages that stretch right across Australia, crisscrossing local groups.

In addition, preliminary historical demographic data for the Alyawarra (Denham MS, Bocquet-Appel personal communication) suggests that their Net Reproductive Rate was essentially stable, with only minor variations, from 1875 to 1927, during an especially turbulent period in the painful history of the indigenous people of Central Australia. Since Aboriginal societies were experiencing colonization and genocide during this period, the fact that Alyawarra population statistics appear to have been stable rather than unstable is counterintuitive, but is entirely compatible with a dynamic equilibrium that dampens fluctuations produced by environmental stresses.

Testing Regionally. The following ethnographic cases with good age data agree (or appear to agree) with predictions from Tjon Sie Fat's (1982) formal mathematical model of all simple helical structures with age-biased matrilateral cross-cousin marriage:

- Alyawarra
- Ambrym
- Karadjeri

- "Murngin"
- Wikmunkan
- Probably Wailbri
- Probably Wanindiljaugwa

And as discussed previously, Dousset (2005) and Brandenstein (1982) document seamless language group exogamy throughout northern, northwestern and western Australia. Their anecdotes are convincing but statistics are absent from those documents.

Northern Territory Administration (NTA) census data for the Alyawarra and adjacent language groups contains imprecise but potentially usable genealogical and demographic data reaching back to the mid-19th century. Relevant documents that appear in References Cited under "Northern Territory Administration" focus specifically on members of the Alyawarra language group, but include a vast quantity of data on additional language group memberships, section / subsection memberships, and intergroup marriages among the Alyawarra (1120 cases) and neighboring groups including Anmatjera (6), Aranda (230), Kaititja (34), Loritja (1), Wagaya (12), Wailbri (36), Warramunga (7) and Yanula (4). Preparation of these data for systematic analysis of language group exogamy among the Alyawarra and their neighbors in the late pre-contact and early contact periods is underway now (Denham MS).

Testing Globally. A global model proposed here should be testable continent-wide. The procedure might be as follows:

- Define S (stress index)
- Test its covariance with
    - SR (Stress Response indicators including polygyny, age skew, Omaha kin terms, etc.
    - E (Exogamy with outside language groups)
    - C (Cognitive matters such as Tjon Sie Fat's helical models, and preferential marriage rules most closely associated with them)
    - E and C would be correlated with each other as two results of SR
- Search for matches and mismatches with predictors of helical structures, asymmetrical marriages and language group exogamy

Although the procedure seems to be rather straightforward, finding adequate statistical data to test the model will be exceedingly difficult. A good beginning might be to start with Keene's (2002, 2004, 2006) reconstructions for contrastive Australian societies at the time of European colonization.

Seeking a General Theory. The mathematical model proposed here provides an economical description of the deep logic underlying reproductively open systems involving moieties, sections and subsections throughout much of Aboriginal Australia. It deals specifically with how that logic serves to integrate societies even when they use different languages and different cognitive models to describe their own local versions of what we view as an ancient continent wide network of networks.

The dynamical model and its component mechanisms trace out how the logic of the mathematical model responds to long term changes in demographic and environmental stresses by altering the slope of the helix, the frequency of polygyny, infant mortality rates, the choice of close-to-distant marriage rules as embodied in moieties, sections and subsections, and the frequency with which Omaha kinship term skewing is employed. Together these features increase or decrease the extent to which the local system reaches outward or folds inward to maintain a perpetual dynamic equilibrium in the context of a continent-wide network of networks.

The models of kinship terminologies that were the mainstays of Aboriginal kinship studies in the 20th century are, in effect, descriptions of the cognitive superstructures that Aboriginal people use to describe and monitor their own behavior. Deriving more from insightful discovery than from creative invention, they are enormously valuable to Aboriginal people who use them to fine tune their interactions. But in fact they sit far above the mathematical and dynamic levels that together constitute the structure and functioning of the continent-wide network of networks.

We suggest that many of the discrete cognitive models now in existence can be brought into conformity with the mathematical and dynamical model introduced here. Attempts to bring existing cognitive models into conformity with our work, or at showing why this cannot be done, can test both the local cognitive models and the general model that we propose. Would such tests demonstrate that we are incorrect *in toto*, in part, or in some of the details?

We are groping toward a foundational model of Indigenous Australian descent, marriage and kinship that encompasses all or most of the continent and spans 40,000 to 60,000 years. And we are doing it speculatively, on the basis of precious little data. Its most accessible surface manifestations are generational moieties and the ubiquitous Dravidian kinship system that are subject to cognitive, interactional, demographic and genetic permutations driven in large part by internal and external stresses. We are deeply concerned with the history of the system, but we do not see it in terms of gradualistic directional change in a form that Charles Darwin and Lewis Henry Morgan anticipated. Rather we speculate that the ancient, enduring, pulsating, homeokinetic Australian system is one of perhaps half a dozen evolutionarily stable states in which human descent, marriage and kinship can persist indefinitely. In the long term, observable changes in sections, subsections, Omaha skewing, reproductive closure, polygyny and the genetics of inbreeding are not directionally cumulative but rather are endless variations on an Indigenous Australian theme, which we suspect may be awesomely resilient.

The mathematical model and the dynamical processes outlined above — opening and closing, expanding and contracting, spiraling like willi-willis dancing on the sand[31] — show striking surface similarities with Woese's flow metaphor[32]:

[31] Willi-Willi is an Aboriginal English term for a whirlwind that has a spiral structure, moves across the desert on hot days, and reaches out to touch - and sometimes overturn - things in its path. This metaphor should not be taken too literally. Intergroup marriage is not causally interrelated to age disparities in

> Imagine a child playing in a woodland stream, poking a stick into an eddy in a flowing current, thereby disrupting it. But the eddy quickly reforms. The child disperses it again. Again it reforms, and the fascinating game goes on. There you have it! Organisms are resilient patterns in a turbulent flow - patterns in an energy flow. … [I]t is becoming increasingly clear that to understand living systems in any deep sense, we must come to see them not materialistically but as stable, complex dynamic organization (Woese 2004:176).

Our objective here is somewhat similar. We prefer to define *stability*, however, in terms of dynamical recoveries from small perturbations that return to an original state, and *structural stability* as the ability to return from instability through other dynamics than the original (e.g., by varying external parameters) that are qualitatively similar to the original dynamic (Jen 2005:8-9). In these terms, over long time spans, Australian kinship might show stability in return from oscillatory responses to periods of stress in some periods but in other periods, such as that of European contact, dramatic instability that might return to structural stability in a new but qualitatively similar dynamic.

A Classical Small World Problem

We are not saying that helical or age-skewed models of Australian kinship such as modeled by Denham, McDaniel and Atkins (1979) or Tjon Sie Fat (1981, 1983) are somehow intrinsically disposed to "open" marriage systems while classical Radcliffe-Brown non-skewed or "European-style" generation models are necessarily endogamous. Some readers will want to draw this conclusion because the classical models of Radcliffe-Brown often imply classificatory brother-sister marriage exchanges, and thus a more "closed" or endogamous marriage system, while the helical models often have classificatory marriage rules that imply directed cycles of marriage exchanges consistent with Lévi-Strauss's notion of generalized exchange. Some readers may see us as saying that models of classificatory marriage rules that imply generalized exchange are more "open" to non-endogamous marriages. This is ***not*** what we are saying and such interpretations are part of the historical confusion about classificatory kinship. We see analogies of this sort as culturally meaningful but from a causal viewpoint as epiphenomena of demographic situations that change from one temporal generation to the next. Hence we should not be taken as saying that helical or age-skewed marriages are somehow direct adaptations to the vicissitudes of a harsh environment.

The adaptive decisions that we see as occurring given the fluctuating vicissitudes of demographic imbalances (such as a lack of mates available through local endogamy), or periods of harsh environmental scarcity, tend to focus primarily of the choice of who to marry. These decisions, which vary from one temporal generation to the next, may affect the extent of different forms of polygyny, including sororal, nonsororal, and mixed variants, and age differences in first, second, and subsequent marriages. Reproductive

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marriage, and similarly the tendency to form helical structures is not causally interrelated to their opening up toward exogamy with increased helical slope and closing with decreased slope.

[32] We offer this image strictly as an evocative metaphor and perhaps as a stimulating visualization – but not in any sense as an explanation – of the phenomena with which we are concerned here.

stochasticity (the distributions of males and females born and living to maturity) and marriage decisions affect the relative scarcity of mates, which with polygyny generally entails (though not always) greater for scarcity of females. Prescriptive endogamy for a reproductively closed small population will eventually lead to extinction.

One of the problems faced repeatedly by Australian groups is to overcome the tendency to marry endogamously within a local group where the available choices for mates are between groups that already have high levels of social and interactive familiarity. This is a classic small-world problem: how to connect and allow connections between those local clusters of network interactions that have become ingrown or endogamous. The "small-world" problem involves the question of how to open up a series of relationally closed local networks within a much larger population to create short average distances between members of different local groups. The contribution of Watts and Strogatz (1998) was to show that if some of the existing links within the clusters can be randomly rewired to connect to the larger population, then even a small number of random rewirings will drastically reduce the average distances between groups. This is not exactly the problem for foraging groups in Australia because of the constraint of physical distances. But small amounts of random rewiring between groups that regularly encounter one another within the distances at which individuals or groups tend to travel or migrate is sufficient to create regional "small-worlds" that have short average distances between any two people in the larger network. And, of course, as transportation improves with the influx of Europeans, effective distance diminishes.

As observed in the contact period, rapid transmission of information about stresses and spousal deficits was a phenomenon known in the Central Australian vernacular by expressions such as "native telegrams." In the 1970s, six degrees of separation got you a trans-continental Aboriginal communication system that worked entirely by word of mouth and often seemed to be as effective and efficient as shortwave radio. Redundancy made it fail-safe for ensuring that potential mates became available through inter-group contacts and communication channels, not only through the effect of random rewirings but meeting places that act as hubs and spokes in the interaction network. As Dousset (2005) and the evidence we have summarized here have shown, the situation was not qualitatively different in the pre-contact period.

In our model of Australian kinship, then, there exists a larger "small-world" framework for finding potential mates in the precontact as well as the contact periods; that is, there always exist ample possibility for finding mates outside the local group, especially between those in neighboring language groups.

Faced off and on with problems of scarcity over successive generations, each local group tinkers with its cultural models, classificatory systems, marriage rules, and ways of instantiating marriage choices within the possibilities offered by a concatenation of these elements within a communicative and behavioral network of relationships.

Tinkering with kinship terms, a group that adopts what we call Omaha terminology is effectively preventing certain endogamous marriages from being instantiated. By

dampening the possibility of marriage within an otherwise marriageable category, the likelihood of an outside marriage is increased. The section system itself— whether 4-, 6- or 8-subsections— acts in a similar manner to restrict local choices in marriage and to increase the likelihood of outside marriages. Increases in polygyny and circumstances in which females accrue to older males, thereby increasing local scarcity of potential mates for younger men, have a similar effect at least among Indigenous Australians and perhaps more generally.

There are, then, a number of core features of Australian kinship that vary dynamically and that push the probability distributions of marriage choices toward marriages with persons or groups that are more distant in terms of kinship links and geography. The classificatory system of Australian kinship is one that is perfectly constructed to allow the integration of "outsiders" into the local group and to push marriage probability distributions toward this possibility by constraining local marriages. In times when local mates are readily available, the possibilities for marriage outside the group may not be utilized, but the existence of these possibilities —and the skewing of probability distributions for marriages according to distances in the kinship network— offer means for a local group experiencing a shortage of mates to marry out and avoid extinction. It is in this manner that the suggestions of our model of Australian kinship and marriage possibilities and probabilities solve what we have called the "Australian paradox."

Conclusion

Swanton thought "the Honoreds" among the Natchez Indians constituted a *descent group* that included men and women, rather than a category of *rank* among men that did not apply to women. The research discovery — motivated by an apparent paradox — from historical texts, was that Honoreds constituted a *rank* instead of a *descent group*. White et al. (1971) relaxed the unrealistic constraint Swanton had mistakenly placed on the data, and the paradox simply vanished, replaced by a weaker model with better fit to the data.

Likewise, traditionally strong axioms favoring mandatory endogamy and reproductive closure make each small Indigenous Australian society appear to be a tightly bounded island unto itself even though doing so would result over time in the extinction of such small societies. By removing ethnocentric European constraints on the concept of *generation*, weakening the axiom for endogamy from a *requirement* to a *preference* whose intensity varies through time, and weakening the prohibition against *implicit* moieties, sections and subsections with regard to logical and behavioral relationships, we believe we have developed more realistic ways of seeing and understanding Indigenous Australian systems of descent, marriage and kinship, relatively free of Eurocentric biases.

By extension, this process may lead to the detection, and possibly the resolution, of other ethnographic paradoxes that would be likely to lead to new research discoveries, some of which, in violating some of the basic assumptions of anthropological thinking, assumptions, and modeling paradigms, may lead to fundamentally new insight and theory.

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