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The Emergence of Order from Disorder as a Form of Self Organization*

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Abstract

Elaboration of individuation is one of the trends in primate evolution. Individuation makes it more difficult to maintain group coherency. Individuation as it occurs in he phylogenetic shift from the Cercopithecoids (Old World monkeys) to African pongids, especially *Pan*, appears to have passed a threshold with *Pan* reverting to smaller, less coherent groups of males and isolated females as a way to deal with increased individuation. In contrast, hominid evolution displays a pattern of group coherency and cooperative behavior that arose in conjunction with the mental construction of relations among individuals that we refer to as genealogical relations. Genealogical relations transcend the limitation of biological kinship as a basis for group coherency, but the combinatorial complexity of all possible genealogical relations becomes problematic with increase in group size. The latter was resolved, it is argued, through the construction of a computational system—a kinship terminology—whose conceptual complexity is independent of the size of a group. This shift to a conceptual/cultural foundation for group coherency changed the dynamics of societal change away from biologically grounded processes of change.

Keywords: complexity, group dynamics, primate behavior, hominid evolution, cultural systems, kinship

1. Introduction

Approximately 8–10 mya (Read, 1975) a Miocene ape species in Africa underwent a speciation event that eventually led to two modern day primate genuses, *Pan* and *Homo*. One genus, *Pan*, still reflects its origins through the Cercopithecoids and Prosimians whereas the other developed a new mode of adaptation based on symbolizing and language that gives the appearance of a break with its evolutionary origins. Though both lines of primates have undergone the same time span of evolution, only one was thrust into a sequence of evolutionary events that led to a primate capable of developing morality, religion and law as part of the social milieu this species has created for itself. This difference between our species—*Homo sapiens*—and all other forms of life has appeared so great as to lead to explication through gods and creation. In scholarly terms, the disparity has been viewed as reflecting "a new order"—a cultural order—in which "Culture is not merely juxtaposed to life nor superimposed upon it, but in one way serves as a substitute for life, and in the other, uses and transforms it . . . " (Lévi-Strauss, 1969, p. 4).

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From a Darwinian evolutionary viewpoint there should be no radical break. If the emergence of language and symbolic systems is simply due to differential reproductive success measured at the individual level then it is appropriate to speak of differences in the tempo of evolution but not of discontinuities. But the Darwinian perspective of evolution driven solely by differential reproductive success acting on variation in the genome of individuals is only one modality for evolutionary change and one that elevates change in genomic structure to a privileged position that does not appear to be in accord with observations about behavior. Behaviors can and do arise that fail to maximize Darwinian fitness. And language, symbols and constructed meanings have enabled change in behaviors to take place on a time scale incommensurate with a time scale for genetic mutations and change in allele frequency via differential reproductive success—the currency of natural selection.

Let us consider behavior to be the outward manifestation of an organism's response to sensory information it has received and incorporated in its internal representation of the characteristics and properties of the environment with which it interacts. Behavior, in this sense, may vary from one organism to another not only in accordance with the biological structures responsible for linking external phenomena with internal states and then to external manifestation of those states through actions taken by the organism, but also according to the how that external information is organized, evaluated and acted upon by the neural system of an organism. As neural systems in different species became more extensive, the link between the genome and the forms and kinds of behavior expressed by the organism with similar genomes has become less rigid. With our species we speak of individuals imitating or learning behaviors or patterns of behavior from the individuals with whom one interacts, and of individuals producing novel behavior—capacities that are not unique to our species—without first requiring change at the genomic level and without equivalent variability at the genomic level.

To account for these more complicated behaviors the Darwinian evolutionary model has been expanded to include the way in which fitness relates not just to the characteristics of a trait expressed by an individual (individual fitness), but can take into account interactions among the provider of sperm, the provider of an ovum and the developing zygote produced through the intersection of the sperm and the ovum. Terms such as mate selection, inclusive fitness, reciprocal altruism, mate investment and parental investment all recognize the importance of behavioral interaction of individuals for a measure of fitness. Similarly, the notion of inheritance of traits has been expanded to include non-genomic inheritance of behavior through individual interaction in the form of imitation and learning (e.g., Cavalli-Sforza and Feldman, 1981; Boyd and Richerson, 1985) as well as the inheritance of concepts and ideas through assessment of those concepts and ideas (e.g., Dawkins, 1989; Durham, 1991) that may lead to novel behaviors.

Despite an expanded view of what constitutes biological evolution, still lacking is an adequate understanding of why and how a shift was made from selection acting at the level of behaviors to selection acting at the level of concepts, symbols and symbolic systems as occurs within the domain that we refer to as culture. Just as biological evolution defined solely in terms of changes in the genomic system does not adequately account for the full range of behavioral complexity that emerged from evolutionary events at the genomic level, evolution defined solely in terms of transmittal of behavior and transmittal of "mental units"

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does not account for the "new order" to which Lévi-Strauss makes reference. Our species is not merely using symbols and is not just engaging in communication through language; we construct rules about how individuals should interact, how societies should be internally organized and even conditions—incest rules and marriage rules—that must be satisfied before reproduction can take place.

2. Social Groups and Behavioral Complexity

The context for Lévi-Strauss's "new order" based on social rules is a social group. To have a social group and not simply a coincidental juxtaposition of individuals implies that the pattern of behavior by one individual takes into account the pattern of behaviors of other individuals in such a manner that group coherence emerges from these interactions. As a first approximation to the idea of a social group, let p be the probability of some future behavior, B, of a specified individual over some appropriate time frame $\Delta t = [t_0, t_1]$. We will say that individuals are social with respect to B over Δt if the value of p includes among its parameter values some measure based on the current behaviors of some subset of individuals in the group. We will say that a group is a coherent group over Δt if the time scale for change in the individuals making up group G relevant to the behavior B is long in comparison to the time scale for observing instances of the behavior B. Coherency of a group in this sense depends upon the ability of one individual to take into account, or "model," the behavior of other individuals in the group.

From the viewpoint of an individual organism, the complexity of a group relates to the number of behaviorally different individuals, where by individual A differs behaviorally from individual B is meant that the behavior of A cannot be predicted from knowing the behavior of B alone. Define a simple society to be one in which (1) there is a single range of behaviors that any individual might manifest and (2) an individual need only take into account the occurrence of these behaviors and not the particular individual manifesting a behavior. In as simple society there will be but a single kind of dyad, a single kind of triad and so on (see figure 1 and Table 1) that can be manifested. For a simple society the behavior of an individual in the group will be comparable over wide ranges of group sizes as individuals need only respond locally to neighboring individuals, neighboring dyads, and so on. If all individuals share the same behavior pattern, then it is not critical for an individual to keep track of both a behavior and the particular individual exhibiting the behavior. As a first approximation, the cognitive demand on an individual scales with the cardinality of the set of behaviors that are possible and not with the size of the group.

Table 1.

Group of n individuals	No. of different behavior sets	No. of different dyads	No. of different triads	Etc.
Simple society	1	1	1	Etc.
Complex society	$n \sim n^1$	$n(n-1)/2 \sim n^2$	$n(n-1)(n-2)/6 \sim n^3$	Etc.

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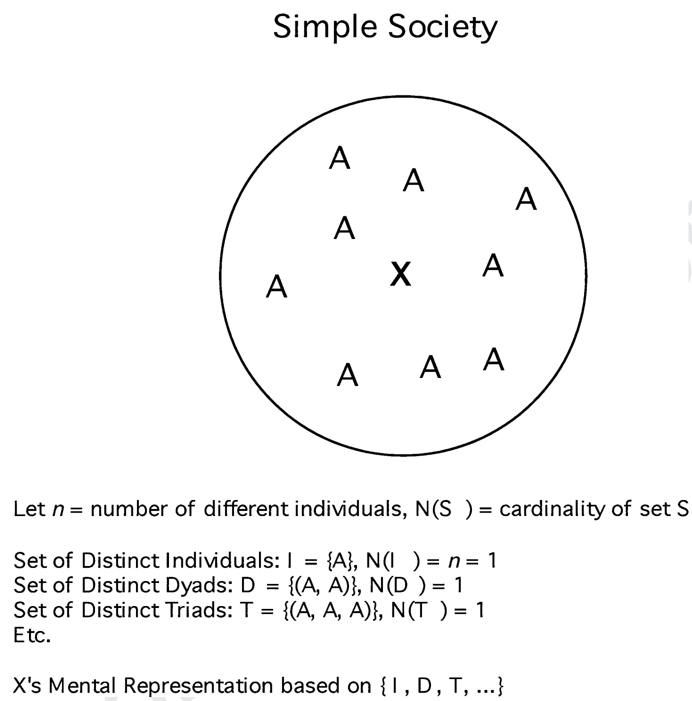

Figure 1. Illustration of the number of different singletons, dyads, triads, etc. in a simple society where each societal member having the same range of possible behaviors.

At the other extreme, define a complex society to be one in which each member of the society is capable of exhibiting a unique behavior(s), so that knowing the behavior of individual *A* does not allow for predicting the full range of possible behaviors by individual *B*. Hence for an individual to align one's behavior in accordance with behaviors occurring within the group, one must take into account all individuals, all dyads, all triads and so on (see figure 2 and Table 1). Thus "a monkey, taking the probable actions of a third party into account, is facing a more challenging world than an animal that only interacts dyadically . . . " (Byrne and Whiten, 1997, p. 11). For a complex society the overall coherence of the group will depend on group size since the componential demands on an individual for aligning one's behavior in accordance with the behavior of all group members increases exponentially with group size when each group member has a distinct set of behaviors. For societies between these extremes the complexity of interactions will be determined by the number of distinct behavior sets, but that complexity will only be partially related to the group size if introducing more individuals does not increase the number of distinct behavior sets.

2.1. *Individuation and Social Complexity*

Presumably inter-individual interaction plays a prominent role in acquisition of information from conspecifics since it is through interaction with other individuals, or sets of individuals,

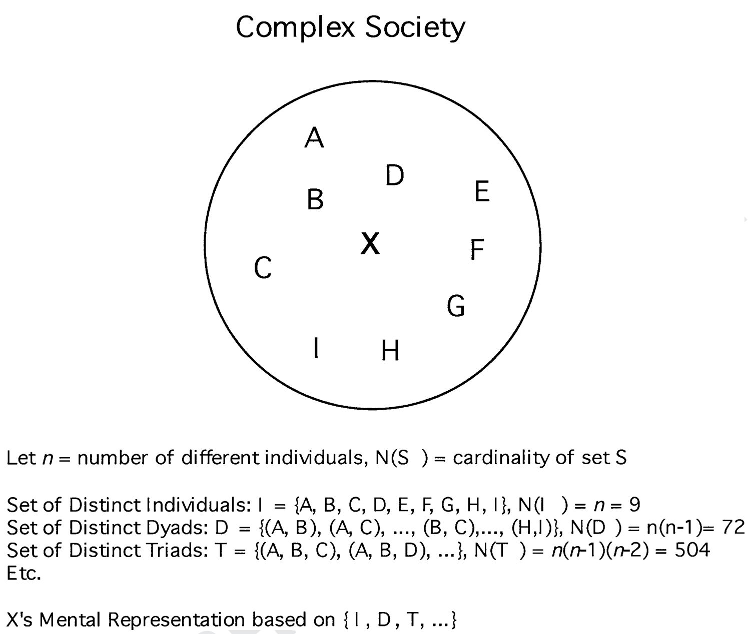

Figure 2. Illustration of the number of different singletons, dyads, triads, etc. in a complex society where each societal member has a different range of possible behaviors.

that the experiential basis for increasingly more accurate anticipation of the behavior of other individuals is obtained. We should expect to find, then, increasing inter-individual interaction as the degree of individuation increases. Not surprisingly, then, non-aggressive interactions between individuals within a group takes on an increasingly important role in primate groups as a means for making one's social world more comprehensible in the face of greater individuation. In addition, with increased individuation one individual must also be able to link a behavior with another, specific individual if behavior is to be modified in accordance with the actions of other individuals. This capacity has been noted with East African vervet monkeys and free-ranging baboons: "these experiments argue that baboons and vervet monkeys recognize the individual identities of even unrelated group members. Moreover, they appear to view their social groups not just in terms of the individuals that comprise them but also in terms of a web of social relationships in which certain individuals are lined with several others. Their behavior is influenced not only by their own recent interactions with others but also by the interactions of their close associates with other individuals' close associates" (Seyfarth and Cheney, 2003). It follows that more complex societies (in the sense defined above) should be associated with species having more advanced neurological systems capable of increased computational and conceptual demands.

Whiten and Byrne (1988) and Byrne and Whiten (1997) have called a positive relationship between intelligence and social complexity the "Machiavellian intelligence hypothesis." They trace the idea back to arguments made by Chance and Mead (1953), Humphrey (1976), and Kummer (1967). Humphrey, for example, suggested that "the chief role of creative intellect is to hold society together" and "social primates . . . must be able to calculate the consequences of their own behaviour, to calculate the likely behaviour of others . . . " (1976, pp. 18, 19). The need for making such calculations was attributed by Chance and Mead to a shift from non-primate mammalian reproduction to primate reproduction in which "primates exhibit a characteristic combination of reproductive features that create the possibility of continuous mating provocation. In no other mammalian group does such continuous mating provocation occur" and so "the probability of continual sexual provocation and competition between males is thus very high" thereby leading to a "unique type of selection" (1953, pp. 39, 40, 48). But it is not only the *frequency* of contexts in which the one individual must take into account the likely behavior of other individuals that is important; the extent to which there is increased individuation also needs to be taken into account. It is the variation in behavior from one individual to another under similar situations and not just the frequency of behaviors that drives the combinatorial explosion illustrated in figures 1 and 2 and Table 1.

With individuation may also come greater inter-group isolation since individuals from one group will be less well known in terms of their behavior from the viewpoint of the individuals in another group, thus making encounters between groups more problematic. In simple societies, groups are made up of individuals sharing the same behavior sets; hence fusion and fission are less difficult since, whether an individual is from one subgroup or another subgroup, the behaviors with which an individual must cope are similar. Thus fission and fusion of groups as a means to accommodate local environmental conditions such as resource density and patchiness is not problematic from the viewpoint of the behaviors that need to be incorporated when fusion takes place. As individuation increases, however, a trade-off arises between the advantages of individuals or sets of individuals moving from one group to another as a way to balance current group size against environmental conditions versus the time needed to be spent in individual interaction as a way to align one's behavior with the behavior of other members of a group and to make the group coherent. With greater individuation there should be negative feedback between, on the one hand, increased interaction of individuals within a group to facilitate internally coherency which then leads to increasing isolation of groups from one another as inter-group transfer of individuals becomes less feasible and, on the other hand, increasing isolation of groups acting as a "push" for greater internal cohesion since fissioning and reformation of groups becomes less feasible as a means to ameliorate conflict within a group.

2.2. Primate Pattern: Old World Monkeys and Chimpanzees

Within the anthropoids we can see a shift in these trends by comparing *Pan* with the Old World monkeys. The pattern among Old Worlds monkeys appears to be one of stable groups of around 20–30 individuals. In some species these are the largest groups (and encounters of groups may evoke either avoidance or aggressive displays but generally not physical contact) and in other species several groups may combine together to form groups of around 10–200 individuals (see Table 2). Group structure centers on matrilines with stable dominance hierarchies among females, which facilitates kin selection as a means for transmitting social behaviors that increase group coherency. Transfer by males is generally

Table 2.

	Grooming	Territoriality	Social structure
Cercopithecoids (Old World Monkeys)	Mainly among biologically related individuals, especially between mothers and offspring (Gouzoules and Gouzoules, 1987 and references therein)	Variable: baboons—no (Hamilton et al., 1976); vervet monkeys—yes (Cheney, 1987) (see Table 22-1, Cheney, 1987); encounter between groups "seldom results in physical contact" (Cheney, 1987, p. 279)	Stable groups around 30–50; aggregates of up to 200 (Kummer, 1968; Crook, 1966; Dunbar and Dunbar, 1975; Sharman, 1981); most males transfer from natal group to neighboring groups (Pusey and Packer, 1987 and references therein); stable female dominance hierarchy
Pan troglodytes (Chimpanzees)	Mainly male-male (59% male-male versus 13% female-female adult grooming, based on Table 7, Nishida, 1979); grooming occurs in reunions of male groups, with grooming directed towards newcomers to the group (Bauer, 1979)	Yes; antagonistic interaction between communities with physical aggression (Wrangham, 1979)	Community—shares single home range, consists of 20–100 individuals but made up of small, unstable male groups (generally <6 for *Pan troglodytes*); community fissioning occurs when there are around 19–20 males; females transfer from natal group; unstable male dominance hierarchies (Nishida and Hiraiwa-Hasegawa, 1987)

to neighboring groups; i.e., to groups with whom there has been prior interaction before transfer. Grooming seems to be primarily directed towards bonds between a female and her offspring. Hence behaviors such as grooming seem to have the function of reinforcing the female linkages that give the group its stability. Stable dominance hierarchies among females increases the predictability of behavior among females, hence allow for individuality within the structure of a stable dominance hierarchy. As noted by Strum et al. with regard to baboons: "the distributed nature of cognition . . . the importance of cognitive work that is done by structure in the world (social and physical) . . . the centrality of co-ordination between individuals in . . . social interaction" all imply that "primate social intelligence may not really be captured by talk of individual tactics and strategies and traditional views of cognition. Situated action, distributed cognition, the challenges and constraints of co-ordination during social interactions, the reality of being part of a system that no one actor could create alone, these may prove more useful way of thinking about primate cognition among baboons . . . " (1997, pp. 73, 74).

In contrast, while chimpanzees (*Pan troglodytes* and *Pan paniscus*) have social organization based on communities with a size range comparable to aggregated groups among the Old World monkeys—around 20–100—the organization of a community is unlike that of Old World monkeys. Though a community tends to be stable through time in terms of its personnel (except for females moving out of the community), it is not a coherent unit on a day-to-day basis but appears to owe its boundedness to highly aggressive and occasionally violent interactions between males from different communities. Internally the community is based on small (<6 for *Pan troglodytes* and >6 for *Pan paniscus*) unstable subgroups of males. When there is reunion of subgroups of *Pan troglodytes* (which may include displays by adult males), grooming behavior is directed by adult males already in the group towards newcomer males. Thus, unlike Old World monkeys where grooming appears to strengthen the female/daughter links that are the basis of group coherency, grooming among *Pan troglodytes* appears to be a means for adult males to establish relations with other adult males entering a subgroup and to re-establish relations among adult males within a group. Dominance hierarchies among males are not stable and subject to challenge by other males. Aggressive conflict between males from different communities is high, including killing of males by the members of one community by the males of another community: "... chimpanzees have aggressive and dangerous intercommunity relationships .... Encounters between different communities carry a risk of severe aggression .... Adult males of the main community repeatedly invaded the territory of the branch community and deliberately killed at least three adult males and one adult female. They were suspected of killing two additional adult males ... " (Nishida and Hiraiwa-Hasegawa, 1987). For *Pan troglodytes* the social problem to be resolved appears to center around interaction among males in a group without close genetic linkages (e.g., genetic father/son linkages) and on the problem of interaction among males with a high degree of individuality.

It appears that the biological mechanisms available for group coherence may have reached an upper limit among the Old World monkeys with regard to the degree of individuation that can be sustained while maintaining group coherence at a size commensurate with efficient foraging. The social structure organized through stable matrilines allows for behavioral traits that relate to group coherence to be transmitted via biological kin selection among females and is expressed in the form of stable female dominance hierarchies. Fission and fusion of troops without aggressive encounters is still feasible.

The pattern among the great apes is strikingly different and suggestive of reverting to smaller social groups as a way to accommodate the cognitive difficulty of dealing with more individualized behavior. The most extreme case is *Pongo pongo* with a solitary social structure, virtually unique among the anthropoids. While chimpanzees have communities based on adult males, the social pattern appears to be one of developing mechanisms that enable group structure to emerge despite a high degree of individuation. Adult females among *Pan troglodytes* are not part of the community structure and appear to have a dispersal pattern similar to that of *Pongo pongo* females (Wrangham, 1979). Apparently *Pan troglodytes* males have developed behavioral mechanisms for forming at least small, unstable groups that can accommodate the higher level of individuation that characterizes *Pan* in comparison with the Old World monkeys. The means for so doing in *Pan troglodytes* appears to center around increased interaction among male adults in the form of behaviors such as male-male grooming as a way to accommodate more individuated behavior. Interestingly, a different means for achieving the same result seems to have arisen in *Pan paniscus. Pan paniscus* appears to have developed an unusual pattern among primate females of using genital rubbing as a way to establish social groupings of females and to ease tensions between communities (White, 1986). For both species of *Pan,* their unique forms of social organization among the anthropoids of bounded communities but without stable subgroups seems to be geared towards developing mechanisms for group formation in the presence of the cognitive complications presented by a incorporating a substantial amount of individuation among group members.

2.3. Hominid Pattern and Hunter-Gatherer Societies

If so, then hominid evolution eventually reverses the Old World Monkey—Chimpanzee pattern of shifting away from large more coherent groups to smaller, less coherent groups as a means to accommodate individuation. In hominid evolution the reversal occurs through introducing a means for social integration despite high levels of individuation. The reversal, I suggest, has been achieved through the construction of culturally constructed kin relations as a way of organizing societies in such a way that kin can be recognized through a conceptual framework rather than through biological properties. This also allows for behavioral alignment to occur on the basis of expected patterns of behavior by culturally defined kin despite a potentially high degree of individuation outside of the context of kinship roles. With hunter-gatherer societies—the form of social organization that prevailed prior to the domestication of plants and animals beginning about 10,000 BP—the general pattern one sees among some of the Old World monkeys of stable groups of around 30 individuals reappears—but for different reasons—and is further elaborated upon. Hunter-gatherer groups typically live in stable residential groups of around 20–30 individuals based on close kin ties. These groups are integrated together in the form of a society of around 500 individuals in such a manner that individuals within the society have access to resources throughout the region occupied by the entire society and not just the resources in the local area of a residence group. Though the Old World monkeys may form temporary, large aggregations, these do not appear to relate to resource procurement, whereas the societal structure of hunter-gatherer groups provides a framework within which individual families benefit, through cooperation, from access to resources throughout the region occupied by the entire society.

The advantage of the hunter-gatherer form of social organization in regions with substantial spatial variation in resource abundance and seasonality of resources variation on a spatial scale comparable to the catchment area of a residential group is straightforward. If the pattern of resource abundance for one group is out of sync with the pattern of resource abundance for another group then the two groups jointly benefit through the sharing of resources when one group has a surplus and the other group has a shortage. A pattern of resources highly variable in time and space would have arisen with the shift by early hominids from a tropical/forested environment in which resource variation occurs on a small spatial scale with limited seasonality to the savanna regions of eastern Africa where there was much greater seasonality of resources and the spatial scale for resource variability was much larger than in more tropical regions.

The difficulty with sharing, though, is that it requires a solution to the Prisoner's Dilemma game; that is, it requires a solution that eliminates the possibility of cheating by one group or the other. The means for so doing, based on extant hunter-gatherer societies, lies in a culturally defined system of intergroup cooperation constructed around culturally defined kin that transcends individual decision making.

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3. Culture: Constructed Conceptual System

By culture I mean a shared, constructed, conceptual system that frames the context within which behavior takes place. A simple example of a "constructed reality" can be seen with the cultural notion of "humanness." By "humanness" I mean the conceptualization (for better or for worse) that members of a society have of themselves in contrast to their conceptualizations of individuals outside of one's society. Whether it be expressed in the form of self-identification of one's group as "the real people" as occurs in many small scale societies, or a religious identification as "the chosen people," or a notion of "civilized people" as occurs with nation/states, the common theme is the presumption that behavior in one's group—in contrast with the behavior of individuals in other groups—is subject to constraints based on shared notions of morality, law, and ethics, hence actions taken by one individual against another individual in one's group that violate norms of expected behavior are subject to censure and punishment.

In the continuous biological cycle of fertilization, birth, growth, reproduction and death, a dividing line between not-human and human is introduced to decide when, in this cycle, an action taken against a biological organism becomes instead an action against a human, hence moral judgement about the action (and punishment) is appropriate, versus when the same kind of action is not subject to moral judgement. In the United States it is evident that two different cultural constructions for that dividing line exist currently with regard to the question of abortion. For those against abortion the dividing line occurs at conception and so abortion becomes morally reprehensible and equivalent to murder. For those in favor of abortion the dividing line occurs at birth and so abortion prior to birth lies outside of moral judgement.

From an analytical perspective, both positions agree that there is a point at which the developing biological entity changes status from simply being a biological entity to one in which humanness has become a feature; the disagreement is on the action that engenders this transformation. In the one case it is by the action of a male through fertilization of an ovum and in the other case it is by the action of a female through giving birth. Neither concept has biological reality, as the notion of humanness is a cultural concept, not a biological feature. And even using a biological stage in the continuous process of life is not necessary for the demarcation between being non-human and human. Some groups such as the Netsilik Eskimo living along Hudson Bay in Canada used a non-biological criterion for the transformation. Among traditional Netsilik Eskimos, humanness entered at the point of naming a newborn by the mother for the spirit that helped her in giving birth to the child (Balikci, 1970).

All three examples of imposing a break in the continuity of biological development share the same conceptual framework of introducing a discontinuity into a continuous process and in all three cases the choice of the discontinuity is arbitrary in the sense that it does not arise from external properties but has been imposed upon external properties and thus depends upon an agreed upon marking point for behavior to be predictable from one individual to another. It is this dual role of both constructing a property that becomes part of the environment in which behavior takes place and sharing this constructed property across individuals that is central to what we mean by culture.

A more elaborated framework arises with symbols and operations (in the mathematical sense) that convert individual symbols into a structured system of symbols. Consider the following statements that relate the concepts, Friend and Enemy:

(1) A Friend of a Friend is a Friend
(2) A Friend of an Enemy is an Enemy
(3) An Enemy of a Friend is an Enemy
(4) An Enemy of an Enemy is an Enemy.

These statements form a conceptual structure and are not simply a model for friends and enemies of actual individuals as it is evident that empirical friends and enemies are only loosely modeled by these four statements. Instead, the four statements indicate the relationships that connect the two concepts, Friend and Enemy, into a structured system of concepts as shown in figure 3. The concepts may be mapped onto individuals (or countries) and the conceptual system expressed by the four statements constructs an order over those individuals through the features of the conceptual structure and not through the features of the individuals (or countries), per se. Prior to the 2003 Iraq invasion, U.S. President Bush categorized nations as being Friends or Enemies not on the basis of empirical evidence of actions taken by those nations, but on the basis of their alignment in terms of the "Axis of Evil". The structure imposed by these four statements is that of a binary opposition. The four statements define an equivalence relation over the entities to which they are mapped

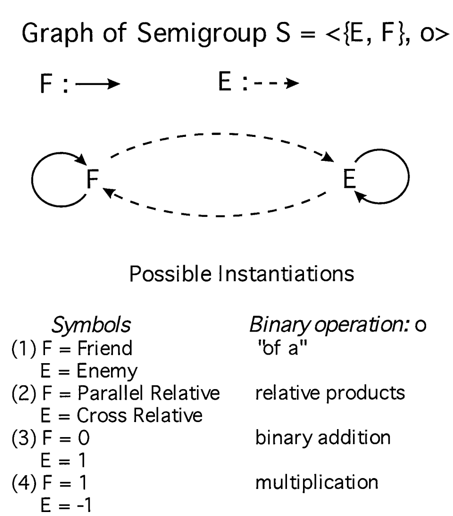

Figure 3. Structure of a conceptual system composed of two concepts, Friend and Enemy.

and the equivalence relation divides the objects into two equivalence classes: the Friend class and the Enemy class.[1]

These two examples illustrate the sense in which culture will be used here as being composed of shared, conceptual constructs imposed on the external world; that is, the "objects" making up culture will be viewed as part of the ideational domain of concepts and ideas (Keesing, 1974) that is mapped onto the phenomenological domain comprised of the world external to us. It will be assumed that cultural distinctions, as shown in the above two examples, do not simply reflect the properties of the phenomenological domain but instead they impose a structure over that domain with properties that need not be derivable from the domain. It will further be assumed that culture, in the sense being used here, must be composed of shared conceptual systems in order for it to provide predictability about behaviors. It is this latter property that enables, it will be argued, cultural constructs to accommodate individuation by also being able to provide predictability when behaviors are formed in accordance with shared cultural constructs.

3.1. Empirical Genetic Relations versus Conceptual Genealogical Relations

The context for the argument will be the transition from primate groups characterized, as discussed above, by social behavior directed towards biological kin (e.g., kin selection) to forms of social organization based on culturally constructed kinship relations. For the former, the empirical structure formed through biological reproduction engendering genetic connectedness for pairs of individuals through a common ancestor (see figure 4) is central to the pattern of social interaction among individuals that can arise through Darwinian selection. The extent to which the behavior of individual X towards individual Y can be introduced through selective benefits arising from social interactions relates to the degree of biological relatedness between X and Y. The standard measure for the biological relatedness

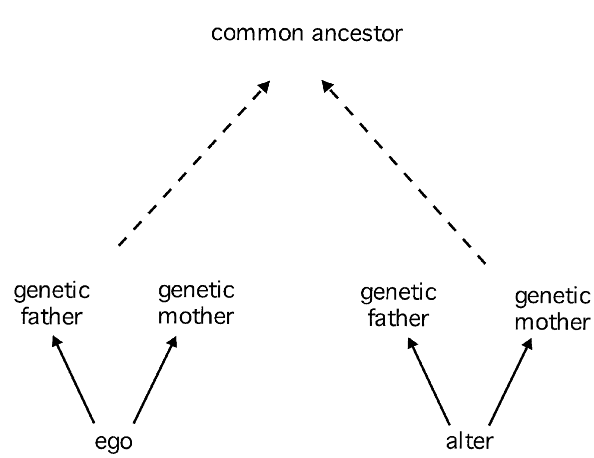

Figure 4. Biological kin relatedness between ego and alter determined by the genetic path from each of ego and alter to a common ancestor (overlapping pedigrees). Kin relatedness varies with $1/2^n$, n the number of steps linking ego and alter.

is the probability, p, of an allele from a common ancestor arriving through two reproductive pathways to both of the individuals X and Y, so that $p = \Sigma(1/2)^{i+j-2}$, where i is the number of parent-child links from X to a common ancestor of X and Y, and j the number of parent-child links from Y to the common ancestor of X and Y. The summation is over all ancestors that X and Y have in common (and the value of i and/or j may vary across the ancestors). The measure of relatedness decreases with 2^n as the number of steps $n = i + j - 2$ increases. As a consequence, kin selection has a limited range of biological kin among whom social behaviors can be introduced through reproductive fitness. And among biological kin, the effectiveness of kin selection is also constrained by the limited mechanisms available for identification of those biological kin. For mammals these mechanisms include the connection between female and offspring arising from biological birth, the connection between genetic siblings due to being raised together and, to a lesser extent, father and offspring links.

When we shift to culturally constructed sets of kin, the closest analogue to the structure of relations formed through the facts of biological reproduction are family trees constructed through genealogical tracing. By *genealogical tracing* I mean the process of tracing recursively from one individual (ego) to another (alter) via a common genealogical ancestor, X; that is, through a finite sequence of individuals, Ego, $A_1, A_2, \ldots, A_m$, X and a finite sequence of individuals Alter, $B_1, B_2, \ldots, B_n$, X, where individual A_{i+1} (B_{i+1}) is either the genealogical father or the genealogical mother of the person A_i (B_i) in the sequence of individuals A_i (B_i) $1 \leq i \leq m$ (n). Formally, genealogical tracing is isomorphic to tracing out genetic connections (compare figures 4 and 5). In terms of content, though, genealogical tracing differs from tracing out genetic connections by providing a way to organize groups of individuals into sets of conceptually linked individuals. The content of the conceptual linkage provided through genealogical tracing is not simply a cognitive model for the empirical facts of genetic relatedness. The individuals identified as genealogical mother and genealogical father are not simply "best estimates" of genetic mother and genetic father.

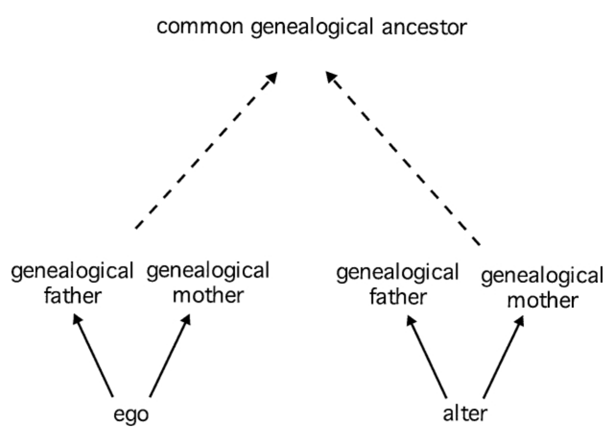

Figure 5. Genealogical relatedness between ego and alter only requires a purported genealogical path from each of ego and alter to a common ancestor (overlapping genealogies). Closeness of the relationship is culturally specified and only loosely related to the number of genealogical steps between ego and alter.

That a genealogy is not simply a "best attempt" to identify biological relations can be seen in the incorporation of spouse as part of the genealogical framework. From a biological perspective spouse is problematic as spouse is not just the "other biological parent" of one's biological child and introduces individuals into genealogical tracing where no genetic connection is involved. In addition, in some instances no conceptual distinction is made between a biological status versus a marital status vis-à-vis the person in question. For example, for English speakers the same kin terms, aunt or uncle, are used equally for the spouse of a biological aunt or uncle and for the biological aunt or uncle.

While it is true that genealogical mother is generally the biological mother, the conceptual basis for genealogical father is highly variable. In some societies (e.g., Australian aboriginal groups) the man currently married to genealogical mother is considered to be the genealogical father regardless of his genetic status with regard to the individual identified as his child. And even in the case of genealogical mother the way adoption is conceptualized in many societies makes it clear that genealogical mother is not simply the genetic mother. In cases of adoption the adopted parents may be as much the genealogical father and the genealogical mother as are genetic fathers and mothers when there is no adoption. Groups such as the Inuit do not make a distinction between one's status as parent through biological birth or through adopting a child (Maxwell, 1996), for example.

In neither of these examples does identification of a woman as genealogical mother or a man as genealogical father who has no genetic relation to the person in question arise simply from ignorance of who the genetic parents may be. Thus it is appropriate to view genealogical tracing as being based upon assignment of genealogical mother and genealogical father in a manner that need *not* be constrained by "best guesses" about the empirical facts of genetic fathers and mothers. Otherwise it would be difficult to account for societies such as the Nayar where it was important to identify some male as the "father" of a child, but whether he was the genetic father was not of any particular concern even when the mother knew who was the genetic father. Consequently, as argued by Read (2001), we can view genealogical tracing as a shift from the phenomenological domain to the ideational domain wherein the empirical, genetic statuses of genetic father and genetic mother have been replaced by the conceptual statuses of genealogical father and genealogical mother and where the content of the relations has no *a priori*, genetic constraint.

3.2. Genealogy and Behavior: Roles

The system of genealogical tracing makes it possible to shift behavior directed towards genealogical kin away from a phenomenological, Darwinian framework in which there must be genetic connection in order for new behaviors to be introduced, to a conceptual framework in which behaviors directed towards genealogical kin identified through genealogical tracing no longer required a genetic connection as a prerequisite for a behavior to be introduced. So long as there is common agreement that a (genealogical) father should act in such and such a way towards his (genealogical) children, for example, the fact of being identified as the father of the children, regardless of one's actual genetic status vis-à-vis those individuals, can trigger both the behavior of the male in question (i.e., he takes on the "father role") and the possibility of sanctions being imposed on him were he to fail to act as a father should act.

In addition, identifying a *conceptual relation* rather than simply the empirical fact of genetic connection as the basis for associating appropriate kinds of behavior has the consequence of allowing other relations, and hence associated behaviors, to be introduced independently of the particular individuals involved. In contrast, the consequences of genetic connections are specific to the individuals in question. If, say, Y is the genetic father of X and Z is the genetic father of Y, then while we can extend the genetic argument to assert that Z is the genetic father of the genetic father of X, this assertion simply identifies a genetic pathway from Z to X. The empirical consequences of this pathway are specific to Z and X and cannot automatically be extended to any other dyad, A and C, where C is the genetic father of the genetic father of A. Whatever empirical implications might arise through selection from the genetic connection between Z and X cannot be transferred to the A and C dyad since the implications of the genetic relation between Z and X are not simply a consequence of the fact that there is genetic relation between Z and X, but are due to the implications that genetic inheritance has for the individuals Z and X. For example, X may have inherited a dominant, deleterious allele from Z such as Huntington's Chorea and died in middle age as a consequence, but this consequence for X of genetic inheritance from Z does not inform us of what will transpire between C and A even if C also has a copy of the allele responsible for Huntington's Chorea; that is, the allele may possibly not be transmitted to A.

In contrast, a conceptual relation such as "genealogical father" can be extended recursively to form new conceptual relations and the new relation and behaviors associated with the relation can be transferred to other dyads as well. Thus, if Y is the genealogical father of X and Z is the genealogical father of Y, then a new conceptual relation, "genealogical father of the genealogical father," linking X and Z may be constructed, thereby making Z the "genealogical father of the genealogical father" of X. But the conceptual relation "genealogical father of the genealogical father" is applicable to any pair of individuals A and C so long as there is an individual B with B considered to be the genealogical father of A and C the genealogical father of B. For such a situation C is the "genealogical father of the genealogical father" of A in the same way that Z is the "genealogical father of genealogical father" of X. Further, to the extent that appropriate behaviors are associated with this new relation[2] (e.g., perhaps a "genealogical father of the genealogical father" is expected to take on an affective role vis-à-vis the other person in the dyad connected by this relation), we expect each of Z and C to exhibit these behaviors when they take on the role, "genealogical father of the genealogical father."

Nonetheless there is a tie to the genetic structure in terms of form if not content. The consequence of genealogical tracing is to construct relations among individuals that graphically have a form similar to the structure of genetic relations based on tracing back genetically from a focal individual, X. In both cases one can, in principle, trace back from X to two individuals differentiated by sex and in both cases this tracing process can be done recursively. At the phenomenological level one arrives at two similar structural forms (though differing in the details of the form) through the same process of recursively tracing from the focal persons to a female person and a male person. In the one case we arrive at a structure of genetic connections and in the other a structure of genealogical connections. The two structures differ, as discussed above, by the fact that genealogical tracing involves conceptual relations, hence relations that transcend the empirical basis of genetic structures. Whether the person Y who claims to be the genealogical father of X is truly the genealogical father of X (assuming a criterion for the assignment of genealogical fathers has been established) is of less importance than whether the claim is accepted by other individuals or not. Person Y can publicly take on the role of a genealogical father, for example, so long as all agree with Y's claim that Y is the genealogical father of X, and whatever behaviors are associated with that role can be engaged in by Y regardless of the veracity of the genealogical claim. Clearly the same is not true of genetic relations. Regardless of any claims that might be made by Y with regard to being the genetic father of X, that claim is factually either true or false. If false, X will not have inherited $1/2$ of her/his chromosomes from Y and so any parenting that Y directs toward X, for example, will not increase the reproductive fitness of Y, and so on.

Consequently, the shift from behaviors arising through reproductive fitness acting through the genetic structure connecting individuals to behaviors associated with conceptual relations and roles has had a profound effect on the formation of social groups and how groups can be organized together in larger units. Group cohesion, for example, can arise through a group being composed of individuals who consider themselves to be genealogical relatives to each other in conjunction with the social behaviors and roles linked to the various relations that can be constructed through recursion. In terms of our hominid ancestors, to the extent that group cohesion translates into competitive advantage with respect to obtaining resources this shift would also have changed the dynamics of evolutionary change away from evolution driven by reproductive success at the individual level (individual competition) to evolution driven by reproductive success at the group level (group competition). In addition, since roles are statuses that individuals can move into and out of, individuation need only be temporarily suspended when taking on a role and acting in accordance with that role. This implies that from the perspective of other individuals, alignment of behavior shifts away from alignment based on "modeling" the behavioral possibilities of individuals as discussed above for primates and illustrated in figure 2, to one of alignment based on behaviors associated with roles. In effect, roles and their associated behaviors provide a simplified social world from a combinatorial viewpoint since roles "*make . . . behaviour predictable, that is expectable in a general sense*" (Klüver, 2002, p. 44, emphasis in the original). Interaction can be in terms of common understanding of roles and associated behaviors (Nadel, 1957, p. 24; Parsons et al., 1965, p. 23) rather than individual cognitive understanding and modeling of the full range of possible behaviors and combinations of behaviors when interaction is in terms of individuals and their behavior sets.

Yet the shift to social organization based around constructed genealogical relations does not escape from the combinatorial problem that arose with individuation. Rather, it shifts the combinatorial problem to a different plane. The combinatorial problem that arises with genealogical relations is due to genealogical relations being defined recursively. If we take into account the two primary genealogical relations, genealogical father and genealogical mother, and the spouse relation, then the number of genealogical pathways connecting a pair of individuals tracing back to a common genealogical ancestor $\sim 3^n$, where n is as defined for genetic relatedness. The value of n may be as large as 12 (tracing from one's great grandchild to one's great grandparent for each of two persons) and $3^{12} = 531{,}441$ distinct genealogical pathways.

4. Kinship Terminologies: Computational Device

The solution found by human societies for dealing with the combinatorial complexity of the genealogical space determined by all of the potential genealogical pathways connecting pairs of individuals resides in the properties of another symbolic system, namely a kinship terminology—the terms of reference used to refer to one's kin. In English these include the terms mother, father, brother, sister, etc. including terms marked with the suffix "-in-law": mother-in-law, father-in-law, son-in-law, etc. In other cultures the terms differ not only in linguistic form but also in the genealogical kin to whom the terms may be applied. In the terminology of the Shipibo Indians (a horticultural group in Peru), for example, terms for genealogical brother and genealogical sister and for genealogical niece and genealogical nephew depend on the sex of the speaker. In addition, sibling terms are used for genealogical cousin (see figure 6). In general, kinship terminologies differ not only through language differences but also through the way genealogical relations are categorized through kin terms.

What appears to be common across kinship terminologies is the way the terminology serves (among other things) as a computational device that permits traversing the space of possible genealogical relations in a conceptually simple manner. The computational power of the kinship terminology arises from being able to calculate kin term linkages among individuals from the logic of the kinship terminology. The logic of a kinship terminology integrates the kin terms into a single, conceptual structure. This conceptual structure makes it possible to compute kin relations in a manner that does not depend upon prior knowledge of genealogical paths connecting pairs of individuals.

The kind of calculation that is used to construct the kin term structure is straightforward. Let three individuals be referred to as ego, $alter_1$, and $alter_2$. If ego refers to $alter_1$ by a kin term, K, and $alter_1$ refers to $alter_2$ by a kin term L, we can define the product of the kin terms K and L to be the kin term, M, that ego would use to refer to $alter_2$. For example, for English speakers if ego refers to $alter_1$ by the kin term Father[3] and $alter_1$ refers to $alter_2$ by the kin term Brother, then ego refers to $alter_2$ by the kin term Uncle.

There is abundant ethnographic evidence demonstrating that kin term calculations of this kind are formulated directly rather than first determining a genealogical pathway and then obtaining the kin term associated with that pathway. As noted by the anthropologist Marshall Sahlins with regard to Moala kinship: "... [kin] terms permit comparative strangers to fix kinship rapidly without the necessity of elaborate genealogical reckoning—*reckoning that typically would be impossible*. With mutual relationship terms all that is required is the discovery of one common relative. Thus, if A is related to B as child to mother, *veitanani*, while C is related to B as *veitacini*, sibling of the same sex, then it follows that A is related to C as child to mother although they never before met or knew it. *Kin terms are predictable. If two people are each related to a third, then they are related to each other*" (Sahlins, 1962, p. 155) (emphasis added). The kin terminology structure enables kin relations to be computed simply by knowing the kin term ego and alter use for a common reference person (see figure 7).

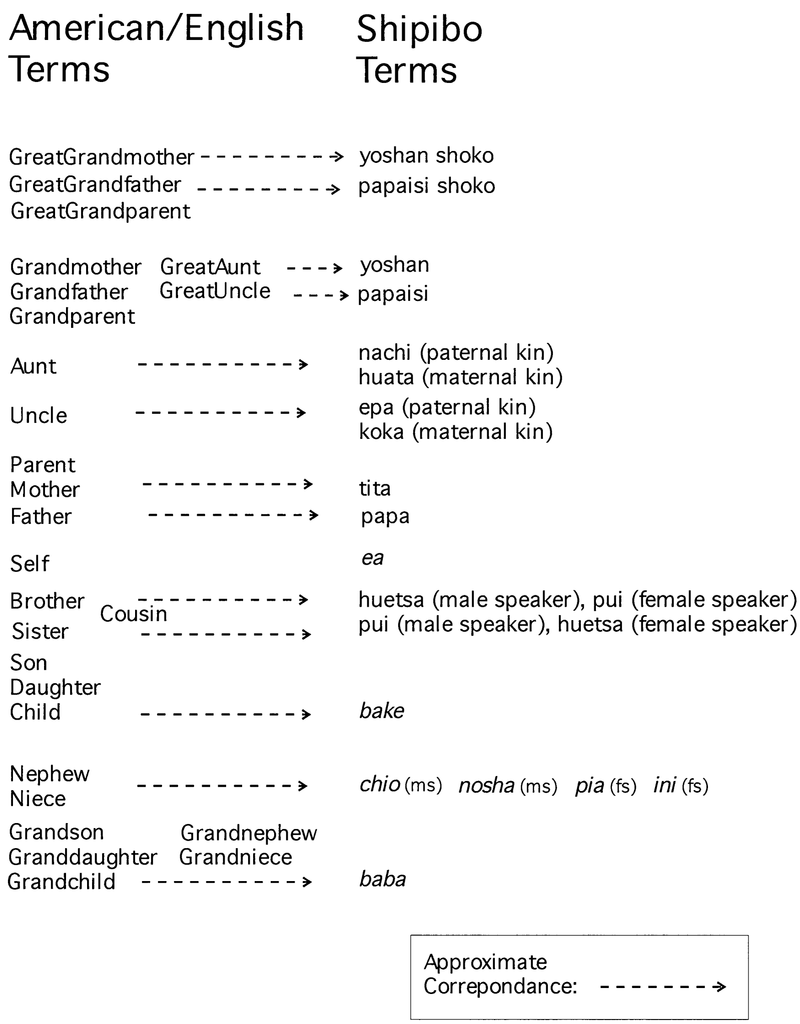

Figure 6. Comparison of two kinship terminologies: American Kinship Terminology and the Shipibo Kinship Terminology.

One particularly salient example of the importance of this kind of kin calculation for social relations is provided by Marshall (1976) in her discussion of how a kin relation is calculated through the kinship terminology by the !Kung san (a hunter/gatherer group living in the Nyae Nyae portion of the Kalahari Desert of southern Africa). "Gao [a Nyae Nyae !Kung] had never been to Khadum [to the north of the Nyae Nyae region] before. The !Kung who lived there at once called him ju dole [dole: 'bad', 'worthless', 'potentially harmful']. He was in haste to say that he had heard that the father of one of the people at Khadum had the same name as his father and that another had a brother named Gao. 'Oh,' said the Khadum people in effect, 'so you are Gao's !gun!a'. . . . " (1976, p. 242)

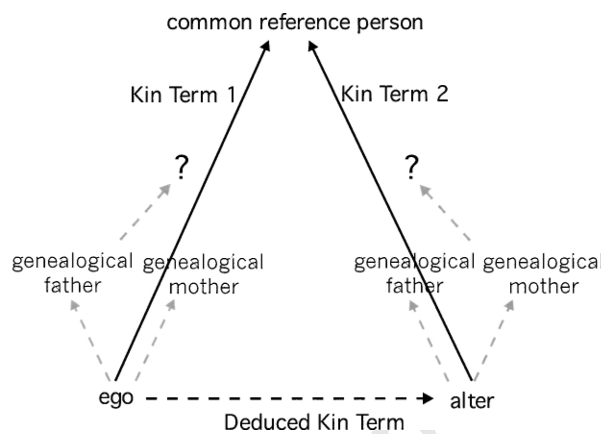

Figure 7. Cultural kinship between ego and alter only requires a common reference person for whom each of ego and alter have a kin term. Ego and alter use the kin terminology structure to deduce the kin term each has for the other person. Closeness of the relationship is culturally specified and may be independent of the number of genealogical steps between ego and alter.

In this example the individuals involved neither have knowledge of a genealogical pathway through which they are connected nor do they need to know about such a pathway before they can determine the kin term they would use for one another. In effect, they determined a kinship relationship, !*gun*!*a*, (a person in the name giver/name receiver relationship with ego) through a kin term calculation that does not depend upon knowing the genealogical connections among the individuals in question. Further, the identification of someone as one's kin is captured by the fact of having a kin term that can be used to refer to another person. One's kin are, as it were, the persons for whom one has a kin term of reference (Read, 2001).

4.1. Kin Term Product

For there to be a computational device that can operate over the genealogical space, the device must be definable separately from the genealogical space over which it will operate. If we think of kin terms as (abstract) symbols, the computational aspect must reside in a logic that permits taking "products" of kin term symbols to arrive at other kin term symbols in a way such that the abstract process of taking products can be translated into operations within the genealogical space and to connections among the members of a group of individuals. An example of this kind of translation process from a symbolic system to the phenomenological level can be seen with the counting numbers and the arithmetic operation of addition.

The counting numbers are symbols that represent a conceptual property, the cardinality of a collection of objects, that can be assigned to a collection of objects in the phenomenological domain. The arithmetic operation of addition is defined at the symbolic level in a manner consistent with translating the symbolic system of arithmetic to the phenomenological domain and actions taken in the phenomenological domain such as combining together

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different collections of objects so as to form a new collection of objects. More precisely, in the symbolic domain when we add a pair of symbols n and m (i.e., a pair of counting numbers) and obtain a third symbol, s, namely the sum of those two numbers, $n + m$, the symbolic assignment $s = n + m$ is done with a logic that ensures compatibility with the cardinality of collections of objects and the formation of new collections by combing together collections of objects. Thus for the symbolic operation $n + m$ we can associate the first number, n, with a collection of objects in the phenomenological whose cardinality is represented by n. Similarly, we can associate the second number, m, with a collection of objects with whose cardinality is represented by that number. Finally we combine these two collections together and we find that the cardinality of this combined collection is the counting number s, and so $s = m + n$ is valid both at the symbolic level and in terms of what the counting numbers represent in the phenomenological domain.[4] The use of the addition operation acting on symbols in lieu of combining collections of objects in the phenomenological domain depends on this translation process for its application to the phenomenological domain. The power of the symbol system of arithmetic lies in the fact that we can do the calculations by using the manipulation of symbols and leave implicit the translation back to the phenomenological domain. In a similar way, the symbolic manipulation of kin term symbols can be translated back into the phenomenological domain of persons and genealogical relations between pairs of persons, but the translation is not necessary and can be left implicit.

The computational system for the genealogical domain has the constraint that it must be generated from a few, basic concepts if it is to serve as a simplification of the way one traverses over the domain of all possible genealogical relations. The primary concept underlying this computational process for kin terms is the product defined over pairs of kin terms discussed above. We can formally define a kin term product as follows:

Definition. Let K and L be kin terms in a given kinship terminology, **T**. Let ego, alter_1 and alter_2 refer to three arbitrary persons each of whose cultural repertoire includes the kinship terminology, **T**. The kin term product of K and L, denoted $K \circ L$, is a kin term, M, if any, that ego may (properly) use to refer to alter_2 when ego (properly) uses the kin term L to refer to alter_1 and alter_2 (properly) uses the kin term K to refer to alter_2.

We can determine the structure for a set of kin terms (i.e., a set of symbols in the mathematical sense of symbols) that is engendered by the kin term product for the kin terms in a kinship terminology by determining the product for each pair of kin terms in the terminology. We can display these products in the form of a table whose entries for the first column and first row are made up of the set of kin terms and whose entry in the intersection of a row and a column is the result of taking the product of the initial terms in that row and column. A table of this kind is called a Cayley Table. The Cayley Table, however, is too general as the number of products in the table is $\sim n^2$, where n is the number of kin terms and so the combinatorial problem (though to a lesser degree) re-arises.

Simplification of the number of distinct products for a set of kin terms relates to the structure engendered by taking kin term products. If this structure can be generated from an underlying "kin term grammar" that identifies how all kin terms can be constructed from a few, primary kin terms using kin term products, then we can reduce the Cayley Table to a simplified table whose number of entries is $\sim n$. Namely, we can construct a table in which the first column is made up of the set of kin terms and the first row comprises the generating terms. Now the size of the table is $\sim n$, hence the complexity of the table varies at most directly with the number of kin terms, which is around 15–20 terms for most terminologies.

For a given kinship terminology, whether or not the complete Cayley Table for the kinship terminology can be simplified in this manner is an empirical question, hence the claim that a terminology has a structure that can be represented with a simplified Cayley Table is subject to falsification.[5] Now consider the American/English terminology. For this terminology the kin terms Mother and Father are plausible candidates for being the generating terms from which the kin term structure is generated.

We can determine the content of the simplified Cayley table by asking informants the kin term that results from taking the product of a kin term with a generating kin term. For each kin term in the AKT, for example, we can ask ourselves (as the informants) the (proper) kin term to be used for alter_2 when ego refers to alter_1 by the kin term K and alter_1 refers to alter_2 by either the kin term Mother or the kin term Father.

We will also introduce the reciprocal kin terms, Son and Daughter, for the kin terms Father and Mother, and take products using these two kin terms as well. Part of the conceptual logic of a kinship terminology is that if ego refers to alter by a kin term K, then there is a kin term, L, the reciprocal kin term, that alter uses to refer to ego.

Next, we introduce the affinal kin term, Spouse, and take products using this term. Finally, we introduce the special symbol Self to serve as the starting point from which products are constructed. Self will be an identity element for the kin term product, hence products with the symbol, Self, do not need to be calculated. When we map the symbolic structure to the phenomenological domain of persons, the symbol Self will be mapped to the reference person for whom kin term relations are being calculated.

4.2. Kin Term Map

We can display the table we construct from informant information in the form of a graph that we will call a *kin term map* (see figure 8). The arrows of the graph correspond to the generating terms and an arrow is drawn from one kin term (including the symbol, Self, as a possible beginning point for an arrow) to another kin term (including the symbol, Self) when the generating term corresponding to the arrow yields the ending kin term for the product of the generating kin term with the kin term from which the arrow originates. The kin term map graphically displays the connections among the kin terms viewed as a computational system. For a kin term and its reciprocal kin term, if K is an ascending kin term then the kin term product $KL = \text{Self}$ and $LK \neq \text{Self}$; that is, for the kin terms Father and Son, Son of Father = Brother $\neq$ Self and Father of Son = Self (i.e., if ego refers to alter as Son and alter refers to alter_1 as Father, then $\text{alter}_1 = \text{ego}$ and so Father of Son maps ego to ego, hence Father of Son is an identity element and so it must be the identity element Self).

The kin term map can be used to determine (proper) kin terms of reference for one person, ego, to use for another person, alter, when the genealogical pathway between these two persons is known. First, we make the correspondence between kin term symbols and genealogical relations via:

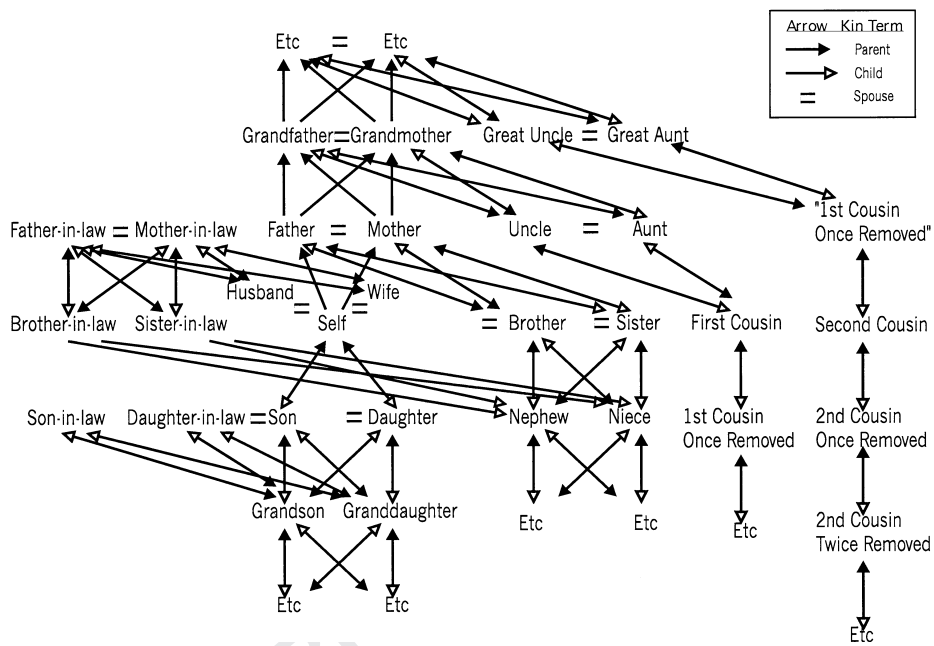

Figure 8. Kin term map for the American Kinship Terminology based on generating terms, Parent (and the reciprocal term Child) and Spouse.

$$
\begin{aligned}
\text{Self} &\leftrightarrow \text{ego},\\
\text{Mother} &\leftrightarrow \text{genealogical mother},\\
\text{Father} &\leftrightarrow \text{genealogical father},\\
\text{Son} &\leftrightarrow \text{genealogical son},\\
\text{Daughter} &\leftrightarrow \text{genealogical daughter} \quad \text{and}\\
\text{Spouse} &\leftrightarrow \{\text{husband, wife}\}.
\end{aligned}
$$

Second, we replace each genealogical relation in the genealogical pathway with its kin term equivalent. Finally, we calculate, using the kin term map, the product of the kin terms corresponding to each of the relations in the genealogical pathway to arrive at a kin term that may properly be used by ego for alter. For example, if alter is ego's mother's brother's daughter, then we have two possible genealogical pathways: (1) alter is ego's mother's mother's son's daughter or (2) alter is ego's mother's father's son's daughter. These correspond to (1) Daughter of Son of Mother of Mother = First Cousin and (2) Daughter of Son of Father of Mother = First Cousin. Hence ego would use the kin term First Cousin for ego's mother's brother's daughter.

4.3. Kin Term Algebra

Note that the arrows for Father and Mother come in pairs in the kin term map for all American/English kin term products. Also note that for the AKT we have the kin term

Parent = {Father, Mother}. Taken together, this suggests that we can use the single term, Parent, as a generating term and then recover the terms Mother and Father by a rule that identifies when a kin term only has a neutral form (such as Cousin) and when a kin term has sex marked forms (such as Mother and Father for the term Parent) in the AKT. Thus, although we began with two generating terms, Mother and Father, we can reduce the generating set to a set with a single ascending term, Parent. A similar reduction in the number of generating terms occurs in other terminologies as well.

In some terminologies such as the Shipibo terminology the parental terms, in this case *Papa* and *Tita*, do not have a neutral form. For these terminologies we can divide the terms into male marked terms and female marked terms. For the terms with a single sex marking there is a single ascending generating term. Consequently, for all terminologies there is either a single ascending term without sex marking such as Parent in the AKT, or we can divide the terms into the set of male marked and the set of female marked terms and for each of these sets we will have one ascending term. This observation provides the basis for what appears to be a general procedure for the production of kin terminologies with an underlying generative grammar.

The general procedure consists of the following steps (see figure 9 for an explicit example).

I. Construct an algebra, **M**, of ascending and descending kin terms by doing:

1. Construct a structure **A** of ascending kin terms based on a single ascending kin term, A, and an identity element, I;
2. Make an isomorphic copy **D** of the ascending kin term structure to form the structure of descending terms generated by the single descending term, D.
3. Make the term D into the reciprocal term for the ascending term A by adding the structural equation $AD = I$. Construct the algebra **M** generated by the generating set $\{A, D, I\}$ and the structural equation $AD = I$.

II. Extend **M** to an algebra with sex marking of products:

1. Make an isomorphic copy **F** of the structure **M** from Step I. Assign the attribute, male, to the terms in **M** and the attribute, female, to the terms in **F**.
2. Add structural equations for products of terms from **F** and from **M** that express the structural properties for the way sex marking are distributed across kin term products.

III. Add rules that determine any particular features of the terminology.

The details of these steps for the American Kinship Terminology are displayed in figure 9. Jointly the construction steps and the rules form a generative grammar that underlies the structural form of the American Kinship Terminology. The structure produced by the generative grammar is shown in figure 11. This structure, with generating set $\{P, C, S, I\}$, and the kin term map based on the terms Parent, Child and Spouse and the symbol, Self, are isomorphic under the mapping $P \leftrightarrow$ Parent, $C \leftrightarrow$ Child, $I \leftrightarrow$ Self and $S \leftrightarrow$ Spouse (Read and Behrens, 1990).

Outline of the Construction of the American Kinship Terminology

(1) Ascending Structure: Semigroup **A** with binary operation o generated by the generating set $G_A = \{i, p\}$, where i is an identity element for the binary operation o.

(2) Descending Structure: Semigroup **D** generated by the generating set $G_D = \{i, c\}$. The semigroups **A** and **D** are isomorphic under the mapping $p \leftrightarrow c$.

(3) Reciprocal structural equation: $p \text{ o } c = i$

(4) Base algebra (structure of ascending and descending terms): Semigroup **B** generated by the generating set $G = G_A \cup G_D$ and the structural equation $pc = i$. The semigroups **A** and **D** are subsemigroups of **B**.

(5) Sex Structure: Let **B*** be a semigroup isomorphic to **B**. Assign the male attribute to the elements in **B** and the female attribute to the elements in **B*** (hence i will be neutral since it is both male and female). Include the cross-sex structural equations (with the kin term equivalent in parentheses): (1) $pp^* = pp$ (Father of Mother = Father of Father), (2) $p^*p = p^*p^*$ (Mother of Father = Mother of Mother) (and reciprocally, (1') $cc^* = cc$ (Son of Daughter = Son of Son), (2') $c^*c = c^*c^*$ (Daughter of Son = Daughter of Daughter), (3) $p^*c = i = pc^*$ (Mother of Son = Self = Father of Daughter), and (4) $cp^* = cp$ (Son of Mother = Son of Father) (and reciprocally $c^*p = c^*p^*$ (Daughter of Father = Daughter of Mother). Let S be the semigroup generated by B and B^*

If **S** is a semigroup with a neutral identity element, i, then a *spouse* element is an element s such that $ss = i$.

(6) Affinal Structure: A spouse element s is added to the semigroup with s satisfying:

(a) $ss = i$ (Spouse of Spouse is Self)

(b) $sp=p$ ($cs = c$) (Spouse of Parent is Parent; Child of Spouse is Child)

(c) $pps = 0$ ($scc = 0$) (Grandparent of Spouse is not a kin term; Spouse of Grandchild is not a kin term)

(d) $psc = 0$ (Parent of Spouse of Child is not a kin term)

(e) $spc = pcs$ (Spouse of Sibling is Sibling of Spouse)

Let **A** be the semigroup generated by $\mathbf{S} \cup \{s\}$.

AKT Sex Marking Rule: (1) if $x \in \mathbf{A}$ and sx is a kin term or (2) x' is the reciprocal of x and sx is a kin term then x and sx will keep their sex attributes. Otherwise, remove the sex attribute. (That is, when Spouse of a Kin Term is a Kin Term then the Kin Term will be stay marked as a male or a female kin term and so will its reciprocal term. However Cousin, for example, will lose its sex marking since Spouse of Cousin is not a kin term).

Ith cousin j-times removed rule: The cousin elements (elements of the form $c^i p^j$, where $i, j \geq 2$), are labeled in a manner such that the labeled cousin terms are self-reciprocal and a maximum number of cousin elements are distinguished by different labels.

Figure 9. Outline of the generative grammar for the American Kinship Terminology.

The algebraic structure not only establishes the fact that the kin term map has a logic underlying its structure as shown in figure 10 for the AKT, but features of the kinship terminology can now be divided into those whose origin lies in the logic of the kin term map by virtue of the fact that they are displayed in the algebraic model for the kin term map and those that are imposed, for cultural reasons, on the kinship terminology. Two important

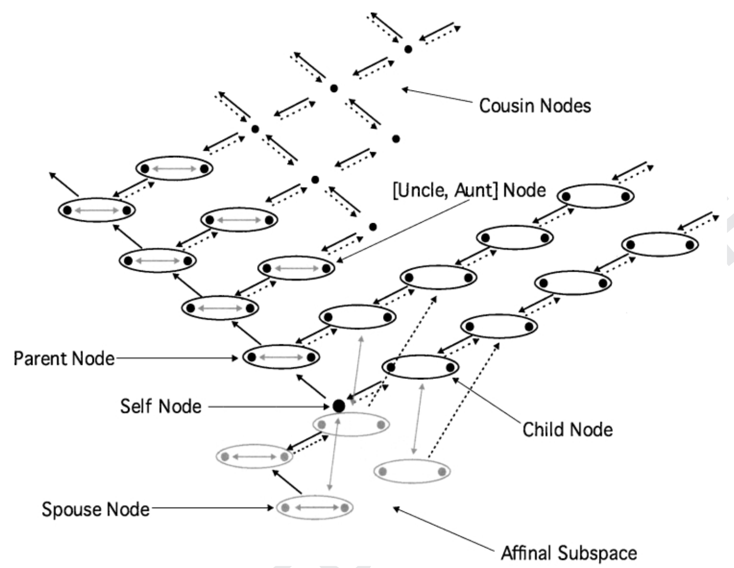

Figure 10. Graph of the algebraic model for the structure of the kin term map displayed in figure 8.

examples of features for the AKT that arise through the logic of the AKT are (1) the criterion by which some kin terms are marked with an "-in-law" suffix and (2) the reason why the "-in-law" suffix is not used for Spouse of Aunt or for Spouse of Uncle (and similarly for Great Aunt, Great Uncle, etc.). The latter observation implies that the "-in-law" suffix is not simply a means to identify kin terms used for relatives by marriage. The failure to use the -in-law suffix has been considered an anomaly that reflects criteria external to the terminology structure such as the degree of affect that a person has for one's aunt or uncle, whether consanguineal or affinal (Schneider, 1980, p. 107, n. 7).

The criterion for the use of the -in-law suffix becomes apparent in the algebraic structure. The Spouse element introduces a "third dimension" in the graphs (nodes in the lower left of figure 10) and it is this set of nodes marked with an -in-law suffix or with the Spouse kin term. In effect, the -in-law suffix distinguishes an affinal subspace of the complete kin term structure.

The failure to use the -in-law suffix with terms such as aunt or uncle by marriage is due to the logic of the Spouse term in the algebraic structure. The algebraic structure identifies the fact that Spouse of Aunt = Uncle and Spouse of Uncle = Aunt as part of the logic of how the kin terminology is generated (see Spouse arrow mapping the Aunt node to the Uncle node and vice versa, figure 10). This property derives from equating Sibling of Spouse with Spouse of Sibling: $scp = cps$.[6]

4.4. *Cultural Instantiation of the Kin Term Algebra*

The kin term algebra is a symbolic system, hence the individuals to whom the terms may be properly applied derives from cultural rules for giving the abstract symbols semantic

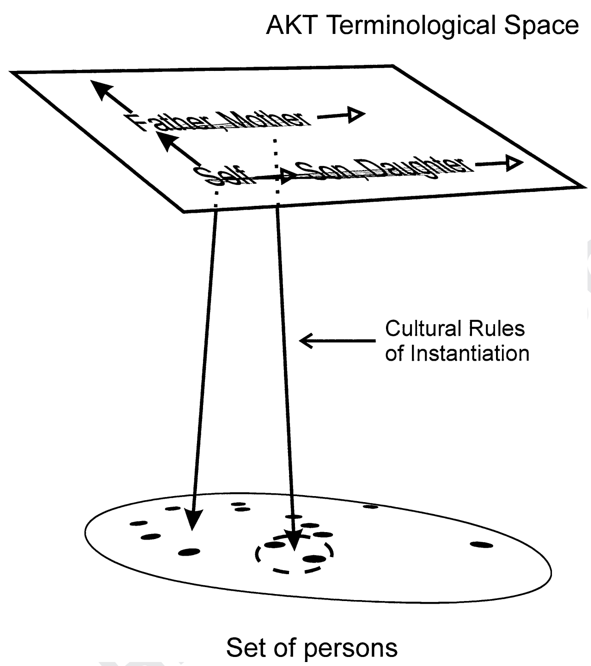

Figure 11. Cultural rules of instantiation provide linkage between the (abstract) culturally specified terminological structure in the ideational domain and a set of persons in the phenomenological domain.

content. I refer to these rules, and the logic of their formation, application and change, as the cultural instantiation of the abstract symbolic structure (Read, 2001, 2003)—see figure 11. We have already had examples of cultural instantiation with the criterion used for the conceptual division between not human and human, and with the concepts Friend and Enemy whose instantiation can include content as diverse as persons, numbers or nations. For the kin term structure cultural instantiation using genealogical relations refers back to the computational problem being solved by the kinship terminology, namely an effective way to traverse over the genealogical domain.

This instantiation has been discussed above with regard to kin terms. We can now extend this instantiation to the symbolic structure. In the case of the AKT we have: $P \rightarrow$ {father, mother}, $C \rightarrow$ {son, daughter}, $I \rightarrow$ {ego}, S $\rightarrow$ {husband, wife}. We can translate any algebraic product into a set of genealogical relations by defining the product of sets of genealogical relations in matrix form. If $A, B \in \mathbf{A}$ and U and V are the sets of genealogical relations corresponding to A and B, respectively; that is $A \rightarrow U$ and $B \rightarrow V$, then $KL \rightarrow V^T \times U$. where V^T is the transpose of the matrix V. For example, $CP \rightarrow$ {father, mother} $\times$ {son, daughter} $=$ {father's son, father's daughter, mother's son, mother's daughter}.

By using this instantiation and the isomorphism between the kin term map and the algebraic representation of the kin term map, we can construct a set of predicted genealogical relations corresponding to each kin term in the AKT; namely, if K is a kin term then $K \rightarrow$

$A \in \mathbf{A}$ and $A = A_1 A_2 \ldots A_n$, say, where $A_i \in \{P, C, I, S\}$. Finally, $A \rightarrow U_1 U_2 \ldots U_n = U$, where $A_1 \rightarrow U_1$, $A_2 \rightarrow U_2, \ldots, A_n \rightarrow U_n$ and U is a set of genealogical relations.

The predicted set of genealogical relations agrees in all cases with the genealogical definition of kin terms given by English speakers (Read, 2001). This, in combination with the previous observation regarding the linkage between genealogical relations and kin terms via the kin term map, establishes that the conceptual structure of the kinship terminology (along with the cultural instantiation of the abstract structure in terms of genealogical relations) provides the basis for traversing the genealogical domain with a computational system independent of the size of the group of individuals involved and independent of the size of the genealogical domain.

Just as the genealogical domain is more encompassing than the genetic structure from which it is abstracted, the terminological space is more extensive than the genealogical domain for which it serves as a computational device. The logic of cultural instantiation does not require that instantiation be limited to genealogical relations. The only requirement is one of completeness in terms of usage of kin terms. For example, adoption may be included under instantiation of the Child kin term so long as any alter who would refer to a genealogical child by a kin term would refer to the adopted child by the same kin term. Hence the legal apparatus in the U.S. in cases of adoption serves to assure to all involved parties that the adopted child is to be considered no differently than a “natural” child and terminologically an adopted child becomes a Child and part of the kinship domain for all relevant persons. This contrasts with the use of the Uncle and Aunt terms as “honorific” terms of address for friends of one’s parents as occurs with many English speakers. The child of the person that ego calls “uncle” in an honorific sense does not become Cousin to ego, hence the extension of the Uncle and Aunt terms would not be included under cultural instantiation of the kin terms.

Once it is clear that the logic of cultural instantiation does not depend on the phenomenological domain it becomes evident why there can be widespread variation among societies in terms of the persons referred to by the local equivalent of the English kin term Father. The kinship terminology is internally consistent as a system of symbols and externally consistent with the phenomenological domain through the process of cultural instantiation, hence the content of that cultural instantiation need not be constrained by the facts of biological reproduction; that is, the cultural instantiation need not be formulated as a “best guess” for the genetic facts of reproduction.

5. Conclusion

As we go phylogenetically from the Old World Monkeys to the great apes, and to *Pan* in particular, we seem to have a trend of increasing individuation that challenges the basis of social cohesion through face-to-face interaction. With increasing individuation groups come up against the combinatorial problem of the number of dyads (and triads) that are possible and for which individuals need to acquire information in order for a group to act in a coherent manner. One solution to the combinatorial problem introduced through increased individuation is to reduce the size of the social group. This may be part of the reason why *Pongo pongo* has no social group above the individual (outside of mother/offspring units) and *Pan troglodytes* females have a social pattern comparable to *Pongo* females. Adult males among *Pan troglodytes* and adult females among *Pan paniscus* appear to have worked out a different basis for interaction (male-male adult grooming and meat sharing for the former and female-female genital rubbing for the latter) as a way to deal with the problems introduced by having a high degree of individuation. Neither species has worked out a solution leading to coherent and stable groups that include both sexes as is true for the Old World Monkeys.

It appears that natural selection was unable to find a biologically based means to make group cohesion possible when there is increased individuation, given the social conflict that arises when individuation includes individuals outside of the range of biological kin among whom biological processes such as kin selection, inclusive fitness, reciprocal altruism, etc. can introduce stable, cooperative behavior. The solution found by our hominid ancestors arose through relations conceptualized between individuals, hence relations that link individuals that are not dependent upon a genetic linkage for their implementation. In modern *Homo sapiens* we refer to these as genealogical relations and they are based on recursively tracing from one individual to another individual via a person identified as the genealogical mother or the genealogical father of that person.

The relations and tracing arise through a conceptually constructed system and are not simply a "best attempt" to model the genetic relations involved in procreation. Ethnographic evidence repeatedly indicates that the individual identified as the genealogical father need not be the genetic father even if the person who is the genetic father is known. And some groups such as the Inuit do not make any distinction between a child through adoption and a child through birth. The shift from an externally driven system (natural selection acting on genetic linkages) to an internally constructed conceptual system had profound implications for our hominid ancestors. The conceptual system of constructed relations "solved" the problem of identifying related individuals who can be presumed to share similar ideas about proper and appropriate behavior, hence laid the basis for cooperative behavior through providing a means to identify likely cooperators.

However, the "solution" to the identification problem for models of how cooperative behavior may evolve and become a stable "strategy" re-introduced the combinatorial problem that arose with individuation, but in a different plane, namely the size of the genealogical domain that is possible under genealogical tracing. The solution to that combinatorial problem was achieved through devising a conceptual system—what we refer to as a kinship terminology—that was simple, yet powerful, and made it possible to traverse over the genealogical domain without detailed knowledge about its structure for a particular group of persons. The kinship terminology is not simply a collection of semantic terms that may be used when referring to one's kin, but a conceptual system with an underlying logic, or grammar, as to how it may be produced and how it relates to the genealogical domain. Human societies have two conceptual domains that can be used for constructing relations between individuals: the genealogical system based on genealogical tracing and the kin term system based on the logic of calculating with kin terms. The results from one system can be translated into the other system. In addition, the kin term system, through the process of cultural instantiation of the abstract symbols making up the terminology, is not constrained in its application to the genealogical domain and has made it possible for human societies to have yet another "distancing" from genetic relations, namely kinship relations that need neither need be limited to genealogical tracing nor to biological reproduction between a husband (genetic father) and a wife (genetic mother) due to artificial means of reproduction.

In effect, human societies have shifted from systems in which evolutionary change are grounded in biological reproduction and genetic relatedness (hence systems where fitness is measured in terms of reproductive success) to systems in which evolutionary change is grounded in conceptual systems of relatedness and, as discussed by Nadel (1957), in the coherency of such systems over groups of individuals. Cultural kinship systems "work" not because of reproductive success per se, but because they provide coherent systems through which societal boundaries are constructed and through which patterns of behavior become predictable through kinship roles, thereby resolving the combinatorial problem that arises with individualistic behavior. Change becomes "cultural change" and the dynamics of cultural change do not reduce to the dynamics of biological change.

Notes

1. See Read (2002) for a more extensive discussion of the Friend/Enemy structure and how it is a structure that reappears in a variety of domains, ranging from binary arithmetic to categorization of kin relations.
2. Due to space limitations I will not delve here into the complex issue of how roles are constructed and evolve in conjunction with expected patterns of behavior (see, for example, Klüver, 2002) and more specifically how roles are associated with kin relations. Suffice it to say that roles and associated patterns of behavior for those roles appear to be ubiquitous in human societies.
3. Kin terms will be capitalized when they are analytically being considered as symbols and not just words used in ordinary conversations.
4. At first glance it might appear that the symbolic operation is defined by first acting in the phenomenological domain and then assigning the counting number s to the symbol $n + m$ based on the actions taken in the phenomenological domain. While it is highly likely that the ontological sequence for the evolution of the conceptual systems of numbers was initially from experience with the phenomenological domain to a system of counting numbers such as 1, 2, 3, many (or its modern folk counterpart 1, 2, 3, . . . , infinity, where infinity has the folk notion of an unimaginably large—but finite—number such as the number of grains of sand on the beach) the system of arithmetic developed in two ways beyond simply combining collections in the phenomenological domain as the basis for assigning symbols when adding counting numbers together. One was the recognition that at a symbolic level there must be a successor counting number for any counting number, whether or not one has a name for this counting number and the second was to develop the logic of the addition operation so that it could be applied to symbols based on the form of the symbolic representation; e.g., the difference in facility between doing addition with the Roman numerals I, II, III, IV, V, . . . and the Arabic numbers 1, 2, . . . , 9, 10, . . . based on the concept of a number, 0, representing the absence of a quantity.
5. This contrasts sharply with formalizations developed for analyzing kinship terminologies based on a genealogical space such as componential analysis and rewrite rules. The former is simply a descriptive formalism (albeit a useful one) and the latter is an unrestricted writing system, hence not subject to falsification.
6. From $scp = cps$ it follows that $scpp = cpsp = cpp^*$ and the product cpp and cpp^* corresponds to Uncle and Aunt, respectively, where by p^* is meant that its instantiation has the opposite sex marking of the instantiation for p. Thus if p is instantiated as father then p^* is instantiated as mother. Hence Spouse of Uncle = Aunt. Similarly, Spouse of Aunt = Uncle.

Disk followed

References

Balikci, A. (1970), *The Netsilik Eskimo*. The Natural History Press, New York.

Bauer, H.R. (1979), "Agonistic and Grooming Behavior in the Reunion Contexts of Gombe Stream Chimpanzees," in D.A. Hamburg and E.R. McCown (Eds.) *The Great Apes*, Menlo Park: The Benjamin/Cummings Publishing Co.

Boyd, R. and P.J. Richerson (1985), *Culture and the Evolutionary Process*. University of Chicago Press, Chicago.

Byrne, R.W. and A. Whiten (1997), "Machiavellian Intelligence," in A. Whiten and R.W. Byrne (Eds.) *Machiavellian Intelligence II: Extensions and Evaluations*, Cambridge: Cambridge University Press.

Cavalli-Sforza, L.L. and M.W. Feldman (1981), *Cultural Transmission and Evolution*. Princeton University Press, Princeton.

Chance, M.R.A. and A.P. Mead (1953), "Social Behaviour and Primate Evolution," *Symposia of the Society for Experimental Biology*, VII, 395–439. Reprinted in (1988), R.W. Byrne and A. Whiten (Eds.) *Machiavellian Intelligence*, Oxford: Clarendon Press.

Cheney, D.L. (1987), "Interactions and Relationships Between Groups," in B.B. Smuts, D.L. Cheney, R.M. Seyfarth and T.T. Struhsaker (Eds.) *Primate Societies*, Chicago: University of Chicago Press.

Crook, J.H. (1966), "Gelada Baboon Herd Structure and Movement: A Comparative Report," *Symposium Zoological Society London*, 18, 237–258.

Dawkins, R. (1989), *The Selfish Gene*. Oxford University Press, New York.

Dunbar, R.I.M. and E.P. Dunbar (1975), *Social Dynamics of Gelada Baboons*. Karger, Basel.

Durham, W.H. (1991), *Coevolution: Genes, Culture and Human Diversity*. Stanford: Stanford University Press.

Gouzoules, S. and H. Gouzoules (1987), "Kinship," in B.B. Smuts, D.L. Cheney, R.M. Seyfarth, R.W. Wrangham and T.T. Struhsaker (Eds.) *Primate Societies*, Chicago: University of Chicago Press.

Hamilton, W.J., R.E. Buskirk and W.H. Buskirk (1976), "Defense of Space and Resources by Chacma (*Papio ursinus*) Baboon Troops in an African Desert and Swamp," *Ecology*, 57, 1264–1272.

Humphrey, N.K. (1976), "The Social Function of Intellect," in P.P.G. Bateson and R.A. Hinde (Eds.) *Growing Points in Ethology*, Cambridge: Cambridge University Press.

Keesing, R.M. (1974), "Theories of Culture," *Annual Review of Anthropology*, 3, 73–97.

Klüver, J. (2002), *An Essay Concerning Sociocultural Evolution*. Dordrecht: Kluwer Academic Publishers.

Kummer, H. (1967), "Tripartite Relations in Hamadryas Baboons," in S.A. Altmann (Ed.) *Social Communication Among Primates*, Chicago: University of Chicago Press.

Kummer, H. (1968), *Social Organization of Hamadryas Baboons*. Karger, Basel.

Lévi-Strauss, C. (1969)[1967], *The Elementary Structures of Kinship*, Revised edition. Translated by Bell, J. Harle, J.R. von Sturmer, and R. Needham. Boston: Beacon Press.

Marshall, L. (1976), *The !Kung of Nyae Nyae*. Cambridge: Harvard University Press.

Maxwell, J. (1996), "Kin Terminology of an Inuit Community," in R.J. DeMallie and A. Ortiz (Eds.) *North American Indian Anthropology: Essays on Society and Culture*, Norman: University of Oklahoma Press.

Nadel, S.F. (1957), *The Theory of Social Structure*. Cohen & West Ltd, London.

Nishida, T. (1979), "The Social Structure of Chimpanzees of the Mahale Mountains," in D.A. Hamburg and E.R. McCown (Eds.) *The Great Apes*, Menlo Park: The Benjamin/Cummings Publishing Co.

Nishida, T. and M. Hiraiwa-Hasegawa (1987), "Chimpanzees And Bonobos: Cooperative Relationships Among Males," in B.B. Smuts, D.L. Cheney, R.M. Seyfarth, R.W. Wrangham and T.T. Struhsaker (Eds.) *Primate Societies*, Chicago: University of Chicago Press.

Parsons, T., E.A. Shils, G.W. Allpart, C. Kluckhohn, H.A. Murray, R.R. Sears, R.C. Sheldon, S.A. Stouffer and E.C. Tolman (1965), "Some Fundamental Categories of the Theory of Action: A General Statement," in T. Parsons and E. A. Shils (Eds.) *Toward a General Theory of Action*, New York: Harper Torchbooks.

Pusey, A.E. and C. Packer (1987), "Dispersal and Philopatry," in B.B. Smuts, D.L. Cheney, R.M. Seyfarth and T.T. Struhsaker (Eds.) *Primate Societies*, Chicago: University of Chicago Press.

Read, D.W. (1975), "Hominid Phylogeny, Neutral Mutations and 'Molecular Clocks'," *Systematic Zoology*, 24, 209–221.

Read, D.W. (2000), "Formal Analysis of Kinship Terminologies and Its Relationship to What Constitutes Kinship (Complete Text)," *Mathematical Anthropology and Cultural Theory*, 1, 1–46.

Read, D.W. (2001), "What Is Kinship?" in R. Feinberg and M. Ottenheimer (Eds.) *The Cultural Analysis of Kinship: The Legacy of David Schneider and Its Implications for Anthropological Relativism*, Urbana: University of Illinois Press.

Read, D.W. (2003), "From Behavior To Culture: An Assessment of Cultural Evolution and a New Synthesis," *Complexity*, 8, 17–41.

Read, D.W. and C. Behrens (1990), "KAES: An Expert System For The Algebraic Analysis Of Kinship Terminologies," *Journal of Quantitative Anthropology*, 2, 353–393.

Sahlins, M. (1962), *Moala: Culture and Nature on a Fijian Island*. Englewood Cliffs: Prentice-Hall.

Schneider, D.M. (1980), *American Kinship: A Cultural Account*. Englewood Cliffs: Prentice-Hall.

Seyfarth, R.M. and D.L. Cheney (2003), "The Structure of Social Knowledge in Monkeys," in F.B.M. Waal and P.L. Tyack (Eds.) *Animal Social Complexity: Intelligence, Culture and Individualized Societies*, Cambridge: Harvard University Press.

Sharman, P.W. (1981), Feeding, Ranging and Social Organisation of the Guinea Baboon, *Papio papio*. Ph.D. Diss., University of St. Andrews.

Strum, S.C., D. Forster and E. Hutchins (1997), "Why Machiavellian intelligence may not be Machiavellian," in A. Whiten and R.W. Byrne (Eds.) *Machiavellian Intelligence II: Extensions and Evaluations*, Cambridge: Cambridge University Press.

White, F.J. (1986), "Party Composition and Dynamics in *Pan paniscus*," *International Journal of Primatology*, 9, 179–193.

Whiten, A. and R.W. Byrne (1988), "The Machiavellian Intelligence Hypotheses: Editorial," in R.W. Byrne and A. Whiten (Eds.) *Machiavellian Intelligence: Social Expertise and the Evolution of Intellect in Monkeys, Apes, and Humans*, Oxford: Clarendon Press.

Wrangham, R.W. (1979), "Sex Differences in Chimpanzee Dispersion," in D.A. Hamburg and E.R. McCown (Eds.) *The Great Apes*, Menlo Park: Benjamin/Cummings.

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