

UCLA

Other Recent Work

Title

The Innovation Innovation

Permalink

<https://escholarship.org/uc/item/2798j162>

Authors

Read, Dwight W
van der Leeuw, Sander E
Lane, David

Publication Date

2009

Peer reviewed

Chapter 2

The Innovation Innovation

Dwight Read, David Lane and Sander van der Leeuw

2.1 Introduction

As humans, we are the only species that reflects consciously on our existence and how we came to be. Such musings have led us to formulate many different scenarios that see us as coming into existence through a creative act by forces outside of ordinary experience. However, within the domain of scientific reasoning, any appeal to such extraordinary forces is excluded. We therefore seek a natural account of how a species as complex as ours, capable of formulating and realizing the widely diverse forms of social systems that we know, could have arisen. Such an account must be embedded in the Darwinian paradigm for evolution, which has been fundamental to our understanding of the way in which biological reproduction can drive change from simpler to more complex biological forms.

The Darwinian evolutionary argument owes its success to Darwin's realization that the engine of reproduction – necessary for the continuation of life forms – is both the location of innovation in the traits that make up an organism, and the driver for change in the distribution of traits in a population. By coupling innovation (in the form of mutation in the genetic material transmitted) with differential reproductive success, Darwinian evolution connects patterning expressed at the level of the individual (novel traits) with patterning expressed at the aggregate level of a population (frequency of traits). Both are components of a single system in which change is driven by the environmental and social conditions responsible for differential rates of reproductive success.

That Darwinian evolution can account for changes in the frequency distribution of a mutation-induced trait in a population is not in question here. Less clear, though, is whether macro-level patterning in the organization of traits within an organism is a reflection of the micro-level of trait occurrence and trait frequency distribution. Or to put it even more broadly, whether collective functionalities arising from systematic

D. Read (✉)

Department of Anthropology, University of California at Los Angeles, 341 Haines Hall,
Los Angeles, CA 90095-1553, USA
e-mail: dread@anthro.ucla.edu

organization of the behavior of individual organisms emerge solely through a Darwinian process that changes the frequency distribution of traits in a population. If, instead, there should be innovation that allows for organizational change through endogenous processes acting on an assessment of current organizational functionalities, then a fundamentally non-Darwinian form of evolutionary change will have come into play. We argue that such an “innovation innovation” did take place during hominin evolution and that it is the basis for the forms of social organization we find in human societies today.

Conceptually, we will develop the argument in two parts. First we discuss the organizational implications of a process – enculturation – that is critical for the transmission of the cultural framework at the core of human social organization. We will show that even though change in social organization begins with properties arising from Darwinian evolution, once enculturation became the means of transmission of cultural resources, our species acquired the ability to construct and transmit forms of social organization in which individual functionality derives from organizational functionality. Such organizational functionality is subject to endogenous change by the individuals involved, and can therefore introduce new functionalities to cope with changing conditions in a manner independent from Darwinian evolution at the level of individuals.

Then, we will discuss a possible evolutionary pathway that may have led to this fundamental change in the basis for societal organization. That pathway leads from social learning, through face-to-face interaction, to the ability to anticipate patterns of behavior from a system of conceptualized relations among group members. This pathway, we argue, arises from a shift in cognitive abilities that enables (1) categorization on the basis of conceptual relations between individuals, and (2) construction of new relations through recursive reasoning (such as “mother of a mother”). Social organization based on such a system of conceptual relations decouples societal organization from biological kinship. Behaviors can be associated with relations, and thereby become part of the interaction of individuals in a network that is itself constructed through the composition of relations. Thus, distribution of social behaviors among a society’s members is no longer dependent upon Darwinian processes enacted at the individual level.

2.2 Organization of Behavior and Collective Functionality

Although the change in cognitive capacities that enabled this fundamental change in humans’ social organization arose through Darwinian evolutionary processes, the changes themselves imply a fundamental shift in the basis for social structure, from the phenomenological domain of traits to the ideational domain of concepts and relations among concepts. Rather than arising from a genetic substrate, these relations are structured and organized through systems of rules that are part of the informational structure we refer to as culture. They provide the framework within which human behavior takes place and frame the interpretations made by societal members of the behaviors of others.

Any social system must combine (1) a means through which the organization of behavior gives rise to collective functionality and (2) a means to perpetuate the social system long enough for functionality benefits to accrue to group members. Behavioral organization is expressed through patterns of interaction among group members. This interaction combines behaviors that are differentially expressed among group members with collective coordination to ensure group functionality, which in turn adds to the functionality of the individuals concerned. *Individual functionality* refers to the consequences for an individual of the range of actions in which he/she is involved. Such consequences can be material when actions are directed towards the phenomenological environment and behavioral when they directed towards the actions of others. *Group functionality* refers to the actions and consequences, including those at the ideational level, that accrue to individuals through membership in a group organized as a social system.

To illustrate this, consider a female/male dyad that forms in a sexually reproducing species – even if temporarily – for the purpose of sexual intercourse. The dyad forms a social group since the action of one member of the dyad affects – and responds to – the behavior of the other. Moreover, the behaviors engaged in by both members are coordinated during their interaction. Group functionality therefore refers to functionality not available to an individual outside of the social group, such as sexual reproduction, and the result of that functionality, namely the production of offspring, adds to individual functionality by increasing individual reproductive fitness.

Whatever may be the coordination of behaviors expressed through, and the functionalities derived from, a social system, both ultimately arise from individual properties that are consequences of Darwinian evolution. But as we are here concerned with proximate rather than ultimate explanations, we need to focus on the means of transmission of the basis for such behaviors from one individual to another. In fact, we can distinguish three modalities for social organization, according to the mode of transmission of behaviors: genetic transmission, individual learning, and enculturation. And as one moves from genetic transmission to enculturation, there is a gradient from individually enacted to socially constituted behaviors that defines the conditions under which effective behavior transmission can occur.

2.2.1 Social Organization and Mode of Behavior Transmission

We next consider some of the implications of each mode of transmission for the organization of behavior and the functionality that arises from it.

2.2.1.1 Social Organization Based on Genetically Transmitted Behaviors

Consider first genetically transmitted behaviors (see Fig. 2.1), i.e. behaviors whose expression arises primarily, if not entirely, from specification at the genotypic level. For the individual, such behavior is enabled through genetic transmission and does not require any social unit other than a copulating couple. If at all, the

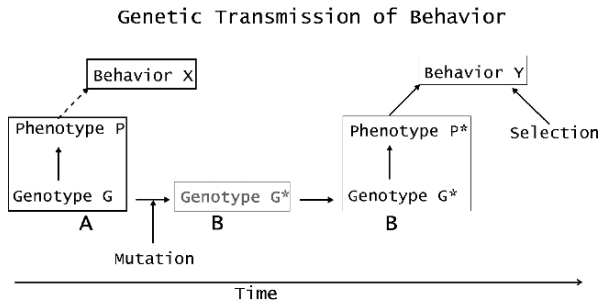


Fig. 2.1 A mutation in the transmission of genetic information from A to B leads to a changed genotype that gives rise to a changed phenotype with a different behavior Y. Selection acts on individual B via the fitness consequences of behavior Y. For diploid, animal organisms a social context other than a reproducing dyad is not necessary for transmission to take place

social dimension arising from organized interaction of individuals comes into play only after genetic transmission has taken place. Coordination of behaviors, and thus the predictability of the behavior of one individual with respect to that of others, derives from differentiated distribution of genetic material over individuals, and is therefore dependent upon the system that structures that distribution.

Social insects are prototypic examples of social systems based on genetically transmitted behavior. The organization of a colony of social insects is derived from a reproductive system that has been co-opted by a single female, the queen, so that her fitness is determined by the functionality of the colony as a whole. The individual functionality of all other females is shifted away from reproductive behavior to behavior that serves the functionality of the colony as a social system. Less extreme than the social insects are mammalian and primate social systems where social organization may also be framed around genetically transmitted behaviors, but without the extreme co-option of reproduction that occurs in the social insects. Old world monkey social units, for example, are often based on a dominance hierarchy for females constructed around genetic mother – daughter linkages that give the social unit cohesion and stability. Such linkages are emphasized through a residence pattern in which female offspring remain in their natal group and sexually mature male offspring migrate to other groups (Pusey & Packer, 1987). Such a social system is based on genetic transmission of behavior, and thus stays within the framework of Darwinian evolution – expanded to include fitness based on interaction with biological kin and sexual selection – since coordination of behavior is embedded in the genetic system (Mitani, Watts, Pepper, & Merriwether, 2002). Perpetuation of such a social system primarily depends on maintenance of a mating system and a pattern for the distribution of adult individuals across residence groups.

2.2.1.2 Social Organization Based on Learned Behaviors

When the linkage between the genotype structure and its phenotypic expression is more relaxed, behaviors are increasingly expressed through individual properties at

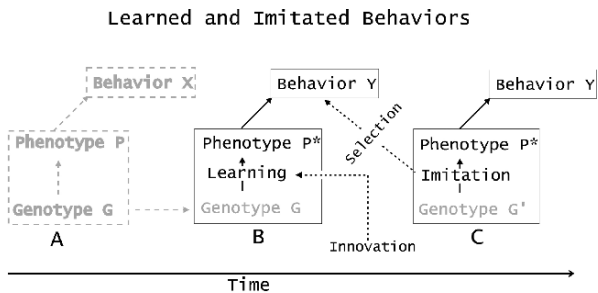


Fig. 2.2 Learning is a source for innovation in behaviors. In the diagram, B is the genetic offspring of A. Behavior X otherwise associated with genotype G and phenotype P has changed to behavior Y in individual B through learning by B. A learned behavior can spread through a population through imitation. Individual C, with possibly a different genotype G', takes on phenotype P* and behavior Y through imitation of B. The imitation process has characteristics due to prior Darwinian selection that frame the conditions under which imitation will occur. Selection arises through evaluation of B as a possible target for imitation by C according to whether the conditions under which imitation will occur are satisfied. Evaluation by C may be based on characteristics of B (“imitate successful individuals”) or it may be based on the consequences that arise from doing behavior Y (“imitate behaviors that lead to a positive reward”) independent of the other characteristics of B. Imitation selection is decoupled from fitness selection

the phenotypic level, and individual learning plays an increasingly important role in the formation and organization of social groups (see Fig. 2.2). Coordination of behavior may now derive from individual learning as well as genetic transmission. Primates are a prototypic example of such social organization, worked out through face-to-face interaction among group members. Among the Old World monkeys, extensive interaction between an infant female and her female biological kin play an important role in determining her position in the female dominance hierarchy as she matures into adulthood. Such social organization requires that offspring be engaged in interactions in which individual learning takes place, so that a new group member becomes incorporated into the group behavior patterns upon which social cohesion is based, and from which collective functionality arises. Consequently, the continued existence of the social group depends upon social interaction, even though the phenotype is being developed through individual learning. Individual learning also leads to behaviors that become part of an individual’s phenotype separate from behaviors acquired through social interaction.

Individual Learning and Darwinian Evolution

When behavior is derived from individual learning, innovation and change can arise outside of genetic mutation, through novel learned behaviors (see individual B, Fig. 2.2). Though innovation by learning plays an analogous role to that of mutation in genetically transmitted behaviors, fitness selection acting on mutations does not have a simple counterpart with individually learned behaviors. While change at the aggregate level of a population can occur as a consequence of individually

learned behavior, thereby affecting the individual learning of other group members, this is not Darwinian selection in the strict sense. However, when there has been selection for changes at the phenotypic/cognitive level that enable one individual to imitate the behavior of another (in the sense of functionally repeating the behavior in a manner consistent with obtaining the outcomes associated with it, rather than merely mimicking it (Shettleworth, 1998; Tomasello, 2000)), this would constitute a strict analogy to fitness selection. But such selection directly derives from how, and under what conditions, imitation takes place (Boyd and Richerson 1985) and is only indirectly related to measures of fitness such as reproductive success (see individual C, Fig. 2.2). Hence, though the means by which innovation and selection take place *are not* identical to mutation and fitness-based selection, if the structural property of innovation leads to patterning at the level of the individual, and operates independently of selection that leads to change at the aggregate level, it *is* functionally the same. Therefore we will include innovation in individual learning and selection through imitation under the umbrella of Darwinian evolution.¹

Individuation Versus Social Cohesion

Regardless of the means by which the organizational structure and its transmission are achieved, all social groups face two problems: (1) how to accommodate (or reject) novel behaviors introduced through mutation or innovation, and (2) how to coordinate group behavior so as to reduce individual conflict within a group. Variation and novelty are problematic for social organization because they introduce behavior that is unpredictable by other group members, and may thus interrupt the coordination from which collective functionality arises.² Social systems, though, may have to accommodate novel behaviors due to biological selection for more complex neurological systems that can process external information and generate novel behaviors (involving learning from past experience and from interaction with other individuals, including imitation) (see Fig. 2.2, individuals B and C). One means to accommodate such novel behaviors is through the cognitive ability to predict, with sufficient accuracy, the behavior of other group members so that an individual may modify its behavior in anticipation of the behavior of others.

With the advent of the primates and especially the evolution of the pongids, the ability to make predictions about behaviors of other group members, including third party group members, has become a regular part of the cognitive repertoire (Tomasello, 1998). Hence, more complex forms of social organization, with

¹ In contrast to social organization based on genetic transmission of behaviors, where group membership is framed around common genetic ancestry, the boundary of a social group organized through interaction of group members is more complex and may bring into play conflicting factors regarding group boundaries. These may be accommodated by the conditions under which individuals can transfer from one group to another.

² At one extreme, accommodation of individual differences and individual learning has been resolved in the negative by the social insects through reducing individual variation by the queen controlling reproduction and the absence of individual learning.

a collective functionality that ensures a fitness payoff for individual group members, have become possible. This interdependence between cognitive capacity and complexity of social organization has been discussed, following seminal papers by Chance and Mead (1953), Kummer (1967) and Humphrey (1976), by a number of researchers under the rubric “Machiavellian Intelligence” (see papers in Whiten and Byrne (1988), Byrne and Whiten (1997b)). Social complexity has been seen as a driving force for increased cognitive capacities among the pongids and hominins (and possibly other social mammals) (Dunbar 1995). Increased cognitive capacity for varied behaviors and the capacity to modify one’s own behavior in expectation of the likely behavior of others has also been posited as an impetus for increased individuation of behavior. But individuation poses problems for social cohesion because it increases the complexity of the social field in which individual group members interact (Read 2004) and augments the potential for conflicts between individuals that disrupt the social units. In the absence of sufficient mechanisms for controlling conflict (Flack, Girvan, de Waal, & Krakauer, 2006) or resolving it (see de Waal, 2000), such conflict can lead to smaller, less diverse and less integrated social units (Read, 2005).

By individuation of behavior we mean expansion of the total behavioral repertoire of group members to the point where the behavior of an individual targeted for interaction cannot be induced accurately from experience with the behavior of other group members. Assume we have a group G of n individuals and let $B_i = \{b_{i1}, b_{i2}, \dots, b_{im_i}\}$ be the repertoire of behaviors that can be engaged in by individual g_i in G , which may have an impact on the functionality of behaviors of other group members. Lack of individuation will correspond to low diversity across the sets B_i and extensive individuation will correspond to high diversity across the sets B_i .

We can then define as a simple society one in which the sets B_i have low diversity, different individuals exhibit essentially the same range of behaviors, and knowledge about one individual’s behavior can successfully be applied to predict the behavior of other individuals (Read, 2004). The group size of simple societies (such as a school of fish or a herd of ungulates) will tend to be scale-free due to low diversity of behaviors across individuals. In such societies, an individual’s social field will be determined by the variety of behaviors within a single, summary behavior set B , rather than by the number of individuals. As a first approximation, if we assume that individuals can cope with all the behaviors in the behavior set B , the complexity of the social field will tend to be independent of the size of the group.

In these terms, a complex society can be defined as one with high diversity of behaviors so that the experience one individual has with another individual may only of limited use in predicting the behavior of yet other individuals. Under these circumstances, the degree of social coherence will be related to the number of individuals for whom behavior is predictable, which will in turn be related to the total number of individuals; hence, social coherence in complex societies based on individual learning will not be scale-free and, all other things being equal, social

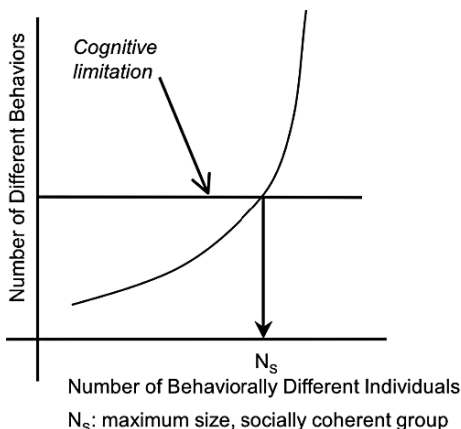


Fig. 2.3 Relationship between degree of individuation (number of behaviorally different individuals) and social complexity (number of possible, different individual, dyadic, triadic, etc.) behaviors. Limit to cognitive capacity for dealing predictably with different behaviors places an upper bound on the maximum size of a socially coherent group

coherence will decrease with group size.³ In a complex society, therefore, the complexity of the social field will scale with the number of individuals in the group *plus* the number of dyads (since a dyad can form a temporary alliance vis-à-vis a third individual), the number of triads and so on. As noted by Byrne and Whiten (1997a: 11): “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” Even if we only take dyads into consideration, the complexity of the social field in a complex society will scale with n^2 , n being the size of the group.

Individuation and Cognitive Limitations

Ability to cope with diversity in behavior depends in part on individual cognitive capacities, and this is reflected in the non-human primates by a positive correlation between innovative behavior and executive (neocortex) brain size (Reader & Laland, 2002). Every species has an upper bound to its cognitive capacities, and (as is shown in Fig. 2.3) that in turn bounds the size of a complex society dependent on coordination of behaviors for its coherence (see also Dunbar (2003)). Hence, in the absence of any new mechanism that enables accommodation of the complexity inherent in increased individuation, the latter will lead to a decrease in the mean group size of coherent social units. The effectiveness of face-to-face interaction for accommodating individuated behaviors diminishes rapidly with increased individuation. This has occurred with the non-human primates who depend extensively on

³ The definition of simple and complex societies introduced here is consistent with the concept of complex systems developed under the rubric Complex Systems Science (see Bourguine & Johnson, 2006).

Table 2.1 Meat Sharing (1 eland), *!Kung san* Hunter-gatherer group, Kalahari Desert, Botswana

Genetic Kin ¹	Number of sharing instances	Non-genetic Kin	Number of sharing instances	Number of different residence groups
Biological Parent	2	By marriage	20	6
Biological Sibling	3	Uncertain	6	
Biological Cousin	9	Other	20	
Other	2			

¹ Biological relation inferred from kin term usage
 Data from Marshall (1976), pp. 300–302

Table 2.2 Food Sharing (Bananas), *Pan troglodytes* (Gombe Stream Reserve)

Group size: <i>n</i> = 37	Biological mother/offspring Connection	No biological connection	Total
Number of dyads	33	625	658
Number of sharing instances	360 (mo → o) 31 (o → mo)	47 (m → f) 17 (other dyad)	457
Rate of sharing (based on numbers in bold)	11.8 instances/dyad	0.1 instances/dyad	Ratio of rates: 100:1

Data from McGrew (1992), pp. 107–108 and Fig. 5.10

face-to-face interaction for social integration. Data on the pongids (orangutans, gorillas and chimpanzees), *Ceboids* (New World monkeys) and *Cercopithecoids* (Old World monkeys) suggest that the pongids show increased individuation as well as a reduction in the size of their social units (see Tables 2.1 and 2.2 in Read, 2005). One pongid, *Pongo pongo* (Orangutan) has reverted to solitary foraging while another, *Pan troglodytes* (Chimpanzee), has developed various kinds of unstable, generally small male groups within a larger, open community of conspecifics (Mitani et al., 2002 and references therein), while females need not be part of any social group. Other pongids have worked out still different “solutions” to the social coherency problem arising from increased individuation of behaviors.

The diversity of solutions to increased individuation suggests that the latter has brought the pongids, our closest non-human primate relatives, up against an evolutionary “barrier” caused by increased individuation. The two primary mechanisms for social integration – familiarity of individuals with one another through face-to-face interaction and biological kin selection for social behaviors between genetically related individuals – apparently cannot cope with the degree of increased individuation and the consequent range of possible patterns for social interaction among wild chimpanzees. Though a chimpanzee community is made up of males with greater biological kin affinity within communities than between them (Morin et al., 1994; Vigilant, Hofreiter, Siedel, & Boesch, 2001), social behaviors are not determined through kin selection (Goldberg & Wrangham, 1997; Mitani, Merriwether, & Zhang, 2000). Instead, they are responsive to age and rank of chimpanzees (Mitani

et al., 2002), that is to small sub-groups in which social learning through face-to-face interaction can occur despite increased individuation of behavior.

We must conclude that face-to-face learning can be overwhelmed by the amount of interaction (and possibly by cognitive overload) needed to maintain social cohesion in the presence of highly individuated behavior, and that biological kin selection may run into limitations due to difficulties in identifying more distant kin, or because biological kin may not be available or suitable (Mitani et al., 2002).

2.2.1.3 Social Organization Based on Enculturation

We next consider the much more complex case of social organization based on a process by which the ideational aspect of the phenotype of an individual (which we refer to as cultural knowledge) develops through what cultural anthropologists have called *enculturation*. As noted by the anthropologist Conrad Kottak (2004: 209):

Enculturation is the process where the culture that is currently established teaches an individual the accepted norms and values of the culture or society in which the individual lives. The individual can become an accepted member and fulfill the needed functions and roles of the group. Most importantly the individual knows and establishes a context of boundaries and accepted behavior that dictates what is acceptable and not acceptable within the framework of that society. It teaches the individual their role within society as well as what is accepted behavior within that society and lifestyle.

Enculturation is the cultural analog to the transfer of genetic information from parent to offspring. Though we may focus on transfer of a single genetic trait for analytical purposes, humans are endowed with a genome made up of 23 pairs of chromosomes, and the ensemble of chromosomes that constitutes our genome is transferred via DNA duplication. Our genome contains both individual genes and organizational information governing the development of an organism through epistatic and other effects among genes. In a similar manner, cultural knowledge transferred from cultural parents and other culture bearers to offspring through enculturation is not just transfer of specific cultural information such as a particular norm or value, but transfer of the complete conceptual framework through which behavior is produced and interpreted by individuals. Just as genetic behaviors are not transmitted directly through sexual reproduction but indirectly via the genetic basis for phenotypic traits, cultural behaviors are not transmitted directly through enculturation. What is transferred is the ideational basis through which culturally based behaviors are constructed. And just as novel behaviors may arise out of individual experience interacting with the cognitive capacities that unfold during phenotypic development, novel behaviors may also arise out of an individual's evaluation of one's cultural development that unfolds during enculturation.

Enculturation begins at birth through interaction between the already enculturated mother and the newborn child and between the newborn child and other enculturated people in its environment (see Individual D in Fig. 2.4).⁴ Such interaction is

⁴ Enculturation is not mechanical information transfer, but a complex process of interaction between less encultured and more encultured individuals (Vinden, 2004), and is analogous to the

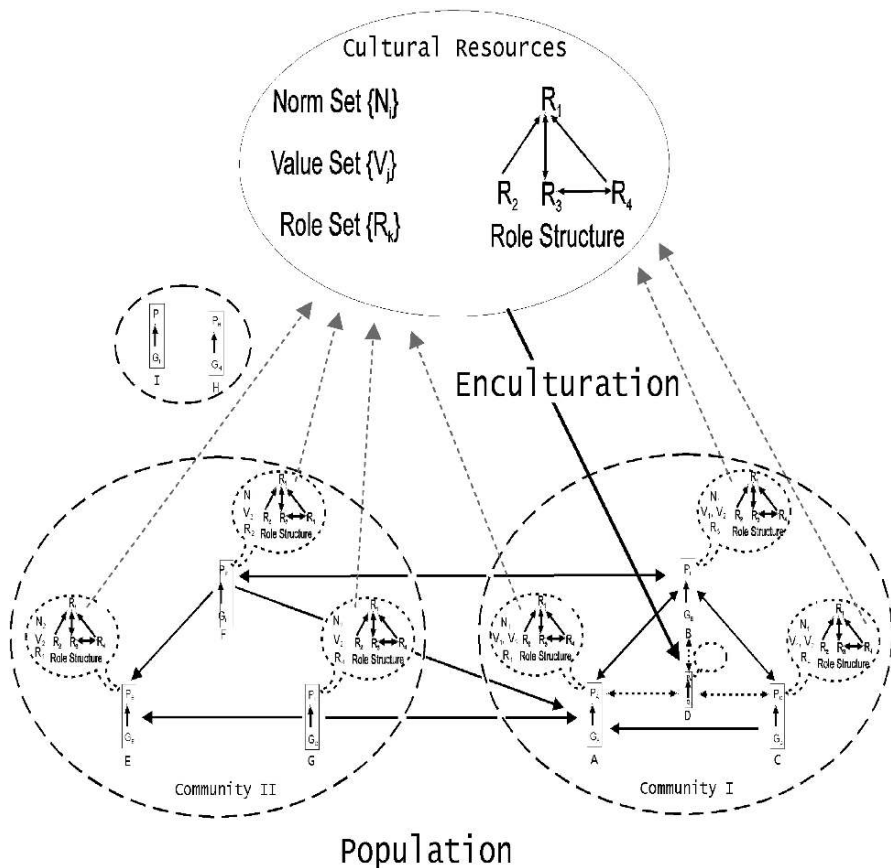


Fig. 2.4 Population of nine individuals (A–I), subdivided into two communities, each determined by shared norms and values but differing between the two communities. Oval at top of figure includes cultural components summed over all individuals (*gray dashed arrows*). Two individuals, H and I, do not share cultural components with the members of the two communities. Individuals A–C and E–G interact according to the one’s role/identity and in accordance with the role structure shared by these individuals (independent of community). Individual D is being enculturated through interaction with A, B and C (dashed arrows) who are already enculturated into the same cultural framework and are members of the same community. The actual pattern of interaction among the individuals need not have a network structure identical to the conceptualized role structure

process of language acquisition. Just as language acquisition continues throughout one’s life, enculturation continues throughout one’s life. Just as languages can be modified (though in structurally constrained ways) during the process of language acquisition, cultural information systems can be modified in structurally constrained ways during the process of enculturation. Just as language acquisition involves the learning of complex semantic and syntactic systems with multiple levels, enculturation involves the learning of complex cultural knowledge systems with multiple levels. Just as language acquisition is error prone and involves means for error correction, so does enculturation.

crucial as it provides the child with “all of the cultural resources that inform both its cognitive processes and the events to which they are applied” ((Schwartz, 1981: 14), shown at the top of Fig. 2.4) and does so by involving the developing child in

...information-rich, culturally structured events. . . Those events are structured by other enculturated persons and by the child as participant. The child learns by acting, acting upon, but also by being acted upon and by acting in pre-structured and other-structured scenes and events . . . The child is immersed in richly structured events upon the natural structure of which, a ‘second nature,’ cultural form, is superimposed (1981: 14–15).

Through enculturation, a child learns the conceptual basis underlying behavioral interaction, allowing it to understand the potential implications of one person’s behavior for another person. This is achieved by transmitting, at one level, the behavior in isolation and, at another level, the meaning given to that behavior as part of a culturally constituted conceptual system. Just as language can convey meanings expressed through linguistically constructed speech acts, behavior can convey meaning expressed through culturally constructed patterns of behavior. When we interact through a role we take on, we are not merely engaging in a behavior, but we are communicating to an audience (with whom we are interacting) the identity and meaning of the role we have taken on. Thereby we are also communicating information about the kinds of behavior that we are likely to engage in, and the likely kinds of behavior we expect in return. For this communication to be meaningful to both sender and receiver, all must participate in the same cultural framework (see Fig. 2.4, Community I and Community II).

Categorization of Behavior and Conceptual Systems

We can illustrate the implications of enculturation for social organization with an example based on categorization of individually formulated notions of “friend-like” and “enemy-like” behavior. In one form or another, categorization is wide-spread because it is a basic means to differentiate behavior according to the kind of entity with which an organism needs to interact, and thus increases the average utility of the interactions of an organism by enabling it to direct appropriate behavior towards the entities it categorizes. Hence, we may assume that some form of categorization is in place even in the absence of cultural categorization resources.

How would this work in practice? Consider three interacting individuals, A, B and C, who are not currently drawing upon cultural resources, and two kinds of behavior: friend-like behavior (including cooperation) and enemy-like behavior (including non-cooperation). At the level of dyads, the individuals may work out interaction patterns based on prior experience: A, through prior interaction with B that had negative consequences, may be induced to exhibit “enemy-like” behavior towards B in the future. Similarly B, through prior friendly interaction with C, may be led to exhibit “friend-like” behavior towards C. The two dyads together represent a simple example of a partial social structure worked out through learned behavior. It is partial because A and C have not yet learned how to interact with each other.

Cultural Computational System and Behavior

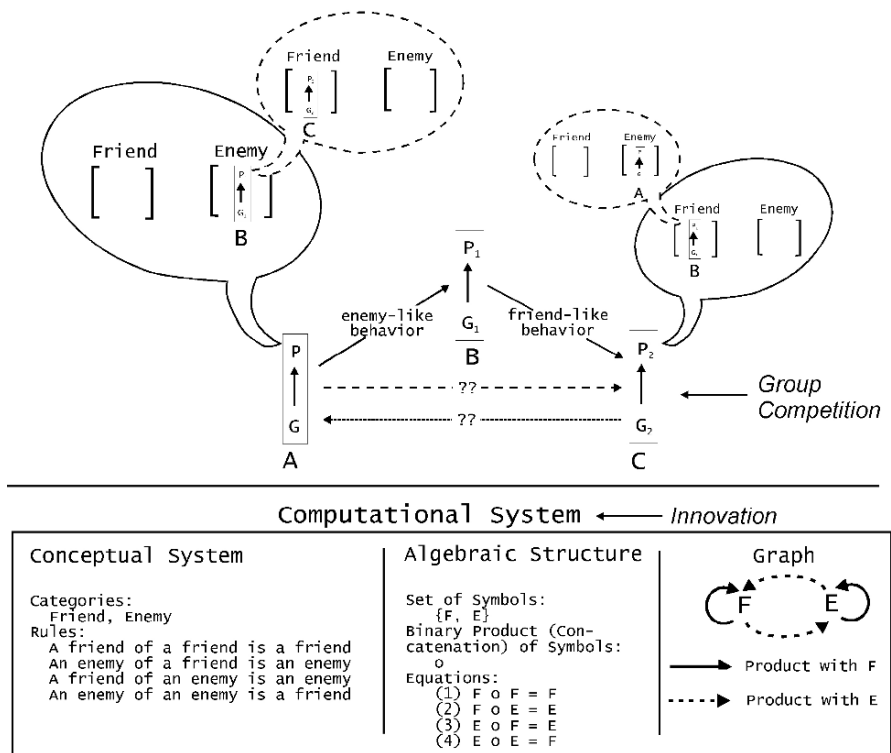


Fig. 2.5 Cultural computation system constructed through cultural rules. *Top of Figure:* First order categorizations (solid “thought clouds”) by A and C of individual B based on their respective interactions with B. Second order categorizations (dashed “thought clouds”) by A and C based on observations of the other individual’s interactions with B. *Bottom of Figure:* Cultural rules linking categories are in the left box. Rules permit computation of culturally proper behavior based on categorizations of individuals. Computations by A and by C will lead to consistent expected and actual behavior when A and C use the same conceptual system through enculturation into the same community. Middle box shows how the conceptual system can be modeled as an algebraic structure. Right box graphically represents the algebraic structure. Innovation can occur at the level of structure and/or in behavioral instantiation of the conceptual system. Competition arises at the group level through group benefit arising through functionality emerging from group organization based on the conceptual system

Now assume that individuals not only learn behaviors, but categorize other individuals on the basis of behavior patterns. Assume A distinguishes two categories, “friend” and “enemy”, and has categorized B as an “enemy” since A interacts “enemy-like” with B (see the “thought cloud” outlined with a solid line pointing to A in Fig. 2.5). If C then categorizes B as a “friend” on the basis of B’s behavior towards C, we again have two dyads constituting a partial social structure, but this time based on categorization. For the two dyads to become a full triad, A and C need

to be able to make reasonably accurate predictions about each other's likely behavior in response to their own actions. Learning to do so through interaction is, of course, not problematic so long as the repertoire of behaviors and number of individuals in the group is not too large, as discussed above.⁵ But when that repertoire has become too large for successful exploration via dyadic interactions, it is more likely that the wrong behavior is adopted. How does A, then, decide on a way to act towards C that is consistent with the way C will likely act towards A but *without* prior interaction?

One solution involves *constructing a computation system* based on the two categories "friend" and "enemy" under the assumption that individuals have both a concept of "self" and a "theory of mind." The former implies that A is "consciously aware" of her/his own categories. The latter means that A believes that other individuals have the same categories ("friend" and "enemy") as she/he does (a second order belief). This is indicated in Fig. 2.5 by the "thought cloud" with a dashed border pointing to individual B, who is categorized by individual A as an "enemy". Further, A, through observing the behavior of B towards C (or by other means), believes that B has categorized C as a "friend". We assume that the same occurs with C (as indicated by the "thought cloud" with a dashed border pointing to individual B as categorized by C as a "friend").

Up to this point we have simply extended the repertoire of beliefs that individuals have about others either on the basis of experience with the other individual (first order categorization) or on the basis of projecting onto the categorized individual *the result of* first order categorization (second order categorization). Extending the repertoire of beliefs does not, in and of itself, lead necessarily to any specific behaviors. That A believes B categorizes C in B's "friend" category does not indicate what behavior A should exhibit towards C. Indeed, the meaning of a category such as "friend", and the behavior to be derived from it, depend upon the definition of the category, i.e. upon the "meaning" of the behaviors involved to the person doing the categorization. In addition, categorization of this kind does not require any coordination between individuals and one person's criteria need not match the criteria of another, even if both conceptualize a category labeled "friend." Finally, there is nothing emanating from the process of categorization that necessarily entails two categories, "friend" and "enemy". One category could be dropped or never defined without affecting the other category.

Cultural Rule System and an Algebraic Model

Now let us expand the two isolated categories, "friend" and "enemy", to a system of categories by using four rules that conceptually link them and thereby form a structure. The four rules are shown in the lower left part of Fig. 2.5. They were chosen because in some societies these four rules are part of the conceptual system linking categories such as "friend" and "enemy", and determine the semantic meaning of the categories when they are used to guide behavior. These four rules

⁵ For completeness, we also assume that the process of categorization and predictions of behavior are dynamic in that they are subject to updating through future interaction experience, but this part of the argument will not be explored here.

determine an algebraic structure – namely a set of symbols, a binary product defined over the set of symbols, and a set of equations that indicate when a symbol product may be simplified to a shorter symbol product, or even to a single symbol. The algebra is formed from the correspondences “friend” \leftrightarrow F, “enemy” \leftrightarrow E, “of a” \leftrightarrow o (the binary operation o) and Rule $i \leftrightarrow$ Equation i ($1 \leq i \leq 4$), as indicated in the bottom middle of Fig. 2.5; the algebraic structure has the symbol set {E, F}. The binary operation may be defined as the concatenation operation for this symbol set, and the four equations indicate when a pair of concatenated symbols may be reduced to a single symbol. The algebraic structure may be graphed by using an arrow to indicate the symbol (F or E) that is produced when a product is made of a symbol with either E or F (lower right side of Fig. 2.5).

If the system of four rules is part of the resources with which individual A has been enculturated, it allows A to make a somewhat more complex computation. Notably, if A categorizes B as “friend”, and believes that B categorizes C as “enemy”, then A calculates C as “friend of enemy,” which reduces to “enemy” via the third rule. A should then categorize C as “enemy”, and exhibit enemy-like behavior towards C. However, thus far the conceptual system only generates a behavior that A should exhibit towards C if A is consistent with A’s conceptual system, but A still has no way of knowing whether or not C is likely to exhibit enemy-like or friend-like behavior towards A. But if both A and C have been enculturated with the “friend/enemy” conceptual system, C will make the computation that A is an enemy of B and B is a friend of C, hence C should direct enemy-like behavior towards A. The result is that A will exhibit enemy-like behavior towards C, and C will (independently) exhibit enemy-like behavior towards A. Thus if A and C are both enculturated with the same conceptual system, A’s expectation about C’s behavior will be accurate and vice-versa.

Observe that the computation system is “useful” for any individual only if all other individuals in the group share the same computation system. Among those individuals sharing the same computation system, and to the extent that behavior is made in accordance with the computations, a consistent and predictable pattern of behaviors will emerge.

The conceptual system will also have implications for the social organization of a group. If we interpret “friend-like” as cooperative behavior, the group will partition into two subgroups where all individuals in a subgroup cooperate with all other individuals in that subgroup and if we interpret “enemy-like” as non-cooperative behavior, individuals in one subgroup will be non-cooperative with individuals in the other subgroup. Under conditions such as those in this example, therefore, a possible evolutionary outcome is that, even though all individuals share the same conceptual system, a single group fissions into two non-cooperative groups as the conceptual system becomes part of the enculturation of individuals.

The Community Boundary Problem and a Computational Basis for its Resolution

How do community members identify other community members except through prior interaction? If a group consists of individuals who share the same conceptual system and individuals who do not (individuals H and I in Fig. 2.4), then, without

prior interaction, a member of a community would not know how to identify the other members (or the non-members). How was this so-called “group boundary problem” resolved in hominin evolution?

Apparently, a special, universal computation system evolved that provides the basis for computing community boundaries of similarly enculturated individuals. That system is built out of the semantic terms we use to define, and to refer to, kin. The kin in question need not be biological kin, because the domain of kin in human societies is culturally, and not biologically, constructed (Read, 1984, 2001, 2005).⁶

Cultural kin are determined through a computation system in the form of a kinship terminology based on genealogical instantiation of kin terms. The system makes it possible to compute from the perspective of one individual, A, whether another individual, B, is among A’s cultural kin, and reciprocally that A is among B’s cultural kin, when both individuals share the same kinship terminological system. But if A and B have enculturated the same kinship terminology, then one may assume that A and B share all other cultural resources that are transmitted through enculturation. Hence an effective behavior strategy becomes: “First determine if an individual is within your kinship domain. If so, assume that person shares your cultural resources and act accordingly. Do not interact with persons who are not within your kinship domain.”

This is precisely the strategy for behavior that occurs, for example, in hunter-gatherer (and other kin-based) societies such as the !Kung san who live in the Kalahari Desert in Botswana. For the !Kung san the word for stranger (*dole*) is also the word used for something that is harmful or dangerous and someone who is not a kin is a stranger, thus bounding social interaction to one’s kin. One’s kin are determined through their kinship system that enables individuals to compute whether they are kin.

The computation system is similar to that of the “friend-enemy” example in that it is also made up of a set of symbols (the kin terms) and a binary product defined over the kin terms. The products for pairs of kin terms can be elicited from users of the terminology and are based on their kin term usage. For example if, in the American kinship terminology, I refer to someone as “uncle” and that person refers to someone as “son”, then I (properly) refer to the last person as “cousin” and so we have as a product for the pair of kin terms “son” and “uncle”: “son of uncle is cousin”.⁷

⁶ This does not mean that cultural kin and biological kin do not overlap as the conceptual basis for cultural kinship ultimately derives from biological reproduction, but cultural kin are constructed through an abstract computation system that removes any causal linkage between biological reproduction and the construction of cultural kin (Read, 2001).

⁷ Product definitions are specific to a terminology as different societies may have non-comparable terminologies; that is, a term in one terminology may not be equivalent to any term in another terminology. Not all kin term products yield a kin term; e.g. for the American kinship terminology Father of Father-in-law is not defined as there is no kin term for the person one’s father-in-law refers to as father.

We have now identified the two basic elements through which human societies are able to circumvent what appear to be severe limitations on group size, while maintaining social cohesion in the face of increased individuation when social organization is based on a combination of genetically based and individually learned behaviors. These elements are (1) a mode of transmission at the ideational level, namely enculturation, that is comparable to the process of sexual transmission at the bio-chemical level of a genetic system, and (2) a means other than prior interaction to identify individuals with whom behavior based on an enculturated ideational system will be appropriate, namely computation of individuals who are mutually kin to each other.⁸ Since the computation system is transmitted through enculturation, reciprocity in kin identification is equivalent to identification of individuals enculturated with the same complex of cultural resources. In addition, reproduction among cultural kin involves cultural restrictions on the conditions under which procreation may occur. Kin computation has consequences similar to restricting sexual reproduction to conspecifics. Both provide a means to sufficiently bound variation in the pool of transmissible traits so that functionality is not lost in the transmission.

Enculturation and Selection: Two Modalities for Selection

Selection provides the balance between what can be transmitted and the implications the latter may have for functionality. In reproductive transmission, a random mutation – which may be deleterious to the functioning of an organism – can be transmitted and selection is then virtually an automatic by-product of the consequences that mutation has on the reproductive success of the receiving organism. In transmission by imitation, such transmission is subject to evaluation of novel learned behaviors, thereby introducing consequences for the phenotype that would not arise under reproductive transmission. Nonetheless this process still is a form of selection activated by individual functionality.

Once enculturation transmission is in place, functionality shifts from individual functionality to group functionality because what is being transmitted addresses group and not individual properties. In addition since the cultural resources are themselves constructions of a past social group, and were carried forward through enculturation, they can be modified by the current social group on the basis of its understanding of its current versus its desired functionality for the individuals involved. Hence, they are subject to change and modification in a manner that is poorly described by a combination of population-based selection and reproductive and imitation-based transmission.

Selection may not be the proper term for this kind of modification given its technical use in Darwinian evolution for processes that lead from individual to aggregate level change in patterning (such as reproductive success). Selection at the cultural resource level has to do with change in a specific cultural resource (such as a kinship

⁸ Appropriate behavior and actual behavior need not coincide for a variety of reasons and discordant behavior can be a signal carrying information about the trustworthiness, or reliability, of one's kin (Biersack, 1982).

terminology, a role structure, a norm or a value), and with its implications for the functionality of a social system of individuals enculturated under that changed set of cultural resources. Yet, this is selection in the non-technical sense and so the term selection will be used here for the evaluations that lead to change in cultural resources. Context should make it clear which meaning of selection is being used.

Selection in the non-Darwinian sense can occur in two ways. Firstly, as *selection that leads to a conceptual system* – which may range from a system enabling computation of categories of individuals (e.g., a system with an algebraic structure), to a system where the roles and the role structure are learned rather than computed, and where individuals may be marked according to the roles they take on (e.g., by special clothing or “scripted” behavior). Such selection will favor cultural resources that can be transmitted in a manner that allows errors to be corrected (e.g., in the form of algebraic and other formal structures), since maintenance of functionality depends on faithful transmission. Functionality obtained from a cultural resource *does not accrue to the group without the enculturation of group members* with that cultural resource. One such functionality that is especially relevant to early hominin evolution is the capacity to facilitate social cohesion in the face of a level of behavioral heterogeneity that would limit socially coherent groups to a size/density suboptimal for the exploitation of their resource base. Another functionality is the use of hunting techniques only available to larger, socially coherent groups. In either case, *the functionality is group functionality, and not individual functionality*, and individuals benefit from the functionality by being a member of the social group.

Secondly, when a shared conceptual system is in place, such as when one group is in competition with another group for access to resources, *group competition at the level of the social group is itself a form of selection*. Such *group competition* depends on the functionality of the social group, and thus on the effectiveness of the shared conceptual system. Hence a group and its organizational structure are in competition with another group and its organizational structure.

Enculturation and Group Competition

If several similar societies (e.g., hunter-gatherer societies) are in competitive equilibrium, under what conditions will a change in organizational structure in one society lead to a new configuration in another? The Lotka-Volterra model of group competition implies (see Read (1987) for details) that two groups in competition will have an equilibrium attractor state when the feedback from the growth of group A has a greater effect on reducing future growth of group A than on growth in group B, and vice versa (see Fig. 2.6, intersecting lines). For example, two hunter-gatherer groups can be in equilibrium even when regions from which they obtain resources partially overlap.

Unlike reproduction transmission, where an increase in individual fitness of any trait in a fitness equilibrium leads to replacement of another traits by the fitter one, group competition involves just a shift in the position of the equilibrium point between the two groups when organizational change in one group makes it slightly more competitive (e.g. by resulting in a slightly higher carrying capacity).

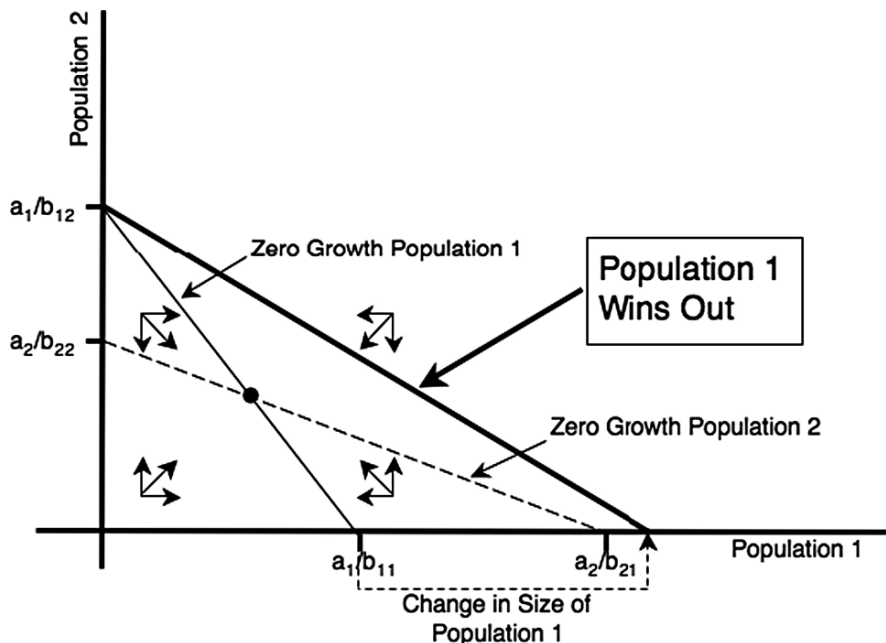


Fig. 2.6 Phase space graph for two populations in competition modeled via the dynamic model $dP_1/dt = a_1P_1(1 - b_{11}P_1 - b_{12}P_2)$ and $dP_2/dt = a_2P_2(1 - b_{22}P_2 - b_{21}P_1)$. Dashed line and light solid line show when P_2 or P_1 , respectively, have zero growth. Intersection of these two lines determines a stable equilibrium between the two populations (solid dot). Only when, say, Population 1 makes a qualitative change in, say, its carrying capacity does the configuration now shift to one in which Population 1 (heavy solid line) wins out in competition with Population 2

Replacement will only occur if one group is substantially more competitive than the other, but not otherwise (see Fig. 2.6, heavy solid line). In effect, a threshold value has to be crossed that is comparable in magnitude to the value for the measure in question. This is precisely the pattern we see in organizational structures for human societies. Hunter-gatherer societies generally consist of up to about 500 people. When replaced by, say, a society with a tribal form of organization, the latter will have a population size substantially larger – often an order of magnitude larger (e.g., 5,000 or more people). Hence, group competition acting on organizational change will give rise to qualitative shifts in organizational structure. This implies that we should see a “step sequence” rather than smooth transitions for organizational structures.

Figure 2.7 summarizes the argument we have developed in this section. The solid vertical line represents the constraint that separates non-human primate social organization from the social organization that developed in the hominins by the time *Homo sapiens* appeared. On the pongid (left) side of the diagram, the combination of increased individuation and social organization based on face-to-face interaction leads to a decrease in the size of social units and the size of social units may have

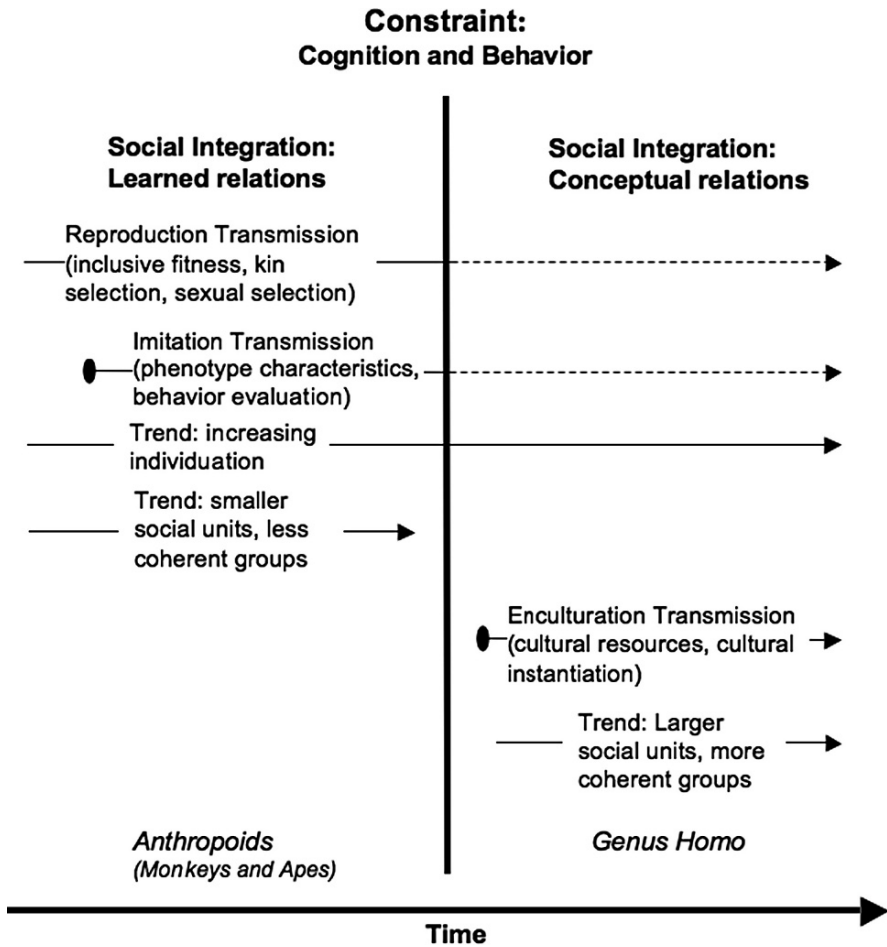


Fig. 2.7 *Vertical line:* Evolutionary barrier for social integration based on individual (reproductive and imitation) transmission due to increased individuation and cognitive limitations. *Solid ovals:* New functionality introduced through Darwinian evolution of cognitive capacities

been sub-optimal for efficient exploitation of resources in the (spatially and temporally) heterogeneous east African open woodland/savannah environment in which they developed. On the hominin (right) side of the line, we posit the advent of a computation system of conceptually formulated, dyadic roles – the basis for cultural kinship systems – that link one individual with another through reciprocal behavior without requiring lengthy prior face-to-face interaction between these individuals. Hence, in so far as expected patterns of behavior are associated with these relations, social integration and group coherence no longer depend on extensive interaction (Rodseth, Wrangham, Harrigan, & Smuts, 1991).

The key conceptual abilities that were needed to make this shift (to be discussed in the next section) do not appear to be present in the non-human primates. Hence, the transition depended upon the introduction of new conceptual abilities. It also shifted the basis for social integration from aggregate level change in a population of interacting individuals, to change in an organizational structure(s) in which individuals are embedded. This shift away from individual fitness-based selection had its precursor in direct transmission of behavioral phenotypes through imitative behavior and individual learning (as indicated in Fig. 2.7). But neither imitation transmission nor reproductive transmission, nor a combination of these, suffices to account for the forms of social organization (and the cultural systems) that eventually arose with the hominins and now characterizes our species.

2.3 Decoupling Social Systems from a Genetic Basis: A Pathway from Darwinian to Non-Darwinian Evolution

We assume that the trend towards increasing individuation of behavior, and the negative impact it had on the coherence of social structure, set the conditions for selection in favor of a new mode of individual interaction. But we are not arguing that increased social complexity, which appears to be part of the evolutionary pathway leading to the pongids and the beginning of hominin evolution about 8 million years go, was due *only* to the trend towards increasing individuation. There were other changes, such as a shift to a frugivorous diet (reducing the range of vegetal resources and the spatial and temporal predictability of resource distribution), which may have led to behavioral changes that added to social complexity. Hunting for meat, a socially complex activity, also becomes part of the behavioral repertoire of *Pan troglodytes*. We are merely using the trend towards individuation to highlight the likelihood of initial Darwinian selection for the cognitive ability to engage in some form of social interaction not dependent on extensive, prior interaction among individuals.

A “bottleneck” limited the domain of possible solutions, so that a solution to the problem of integrating individuation with social cohesion did not arise even with the cognitive capacity of the chimpanzees, despite the 8 million years that elapsed between our common primate ancestors and the development of modern chimpanzees. It is only with hominin evolution that these inherent limitations on the size of a coherent social group were circumvented, by means other than elaboration of face-to-face interaction and imitation of behaviors.

For social interaction to be systematic, it must be reciprocal, ongoing and not just episodic. As a consequence, biological means for facilitating social interaction depend either on some form of biological kin selection or on a way to identify individuals predisposed to engage in reciprocal and positive social interaction. Behaviors repeatedly directed towards either non-biological kin or non-reciprocating individuals favor selection for non-social interaction (e.g. “cheating”) on the part of the recipient, since the latter benefits without engaging in positive, reciprocal behavior.

A limit to the size of primate social groups integrated through biologically based (rather than learned) social interaction arises from the relatively few means available to primates for identifying biological kin. Such means may arise indirectly from interaction with biological kin, primarily between female genetic parents and offspring, or between biological siblings raised together. But, even if more distant biological kin can be “identified” through patterns of behavior (as in the case of sexually maturing females remaining in their natal troop), the effectiveness of such biological kin selection in biasing behavior in favor of reciprocal social interaction decreases exponentially with genetic distance. Identification of non-biologically related individuals predisposed to engage in reciprocal social interaction is even more problematic.⁹

While we cannot yet identify the precise conditions laying the cognitive foundations for a new mode of social interaction that eventually became decoupled in its implementation from a biological substrate, the existence of such a new mode is evident from the fact that our species, *Homo sapiens*, has found the means to accommodate both increasingly individuated behavior and larger social units in a coherent and effective manner that addresses the collective interests of the group. The magnitude of this shift in the basis for social integration is evident in three major differences between our non-human primate relatives and ourselves.

First, even in the smallest and simplest of modern human societies, namely hunter-gatherer societies, the number of individuals integrated together is between one and two orders of magnitude larger than the size of social units found among the pongids. For example, the !Kung san hunter-gatherers mentioned above live in groups of about 30 individuals (Lee, 1990) integrated together as a single society of about 500 individuals, whereas pongids such as the chimpanzees have unstable social units with around 6–20 males (Nishida & Hiraiwa-Hasegawa, 1987). The individuals in a single hunter-gatherer society are divided into residence groups that may be spatially isolated yet allow for frequent, non-disruptive movement of individuals from one group to another during the life cycle of individuals. In contrast, non-human primates are typically organized into small social units between which there are often antagonistic relations (due to territoriality) and for which change in social unit residence of adults (especially males) is usually highly disruptive and infrequent.

Secondly, hunter-gatherer societies have a pattern of food sharing that need not be structured around biological kin relations and may involve different residence groups (see Table 2.1), whereas food sharing among non-human primates is not common and when it does occur, almost exclusively concerns vegetable food exchange between females and their offspring or occasionally from a male to a female (see Table 2.2, entries in bold), apparently as a way to gain access to a female for reproduction (McGrew, 1992).¹⁰

⁹ The difficulty of circumventing this limitation can be seen in the fact that the non-human primates have not yet found a way to resolve this biological limitation even after more than 8 million years of Darwinian evolution.

¹⁰ Patterns of food sharing among chimpanzees are more complex when meat sharing is taken into consideration and extensive variation occurs among hunter-gatherer groups with regard to when

Third, in contrast to a bounded primate troop based on face-to-face interaction, the social boundary of a hunter-gatherer society is defined by the set of individuals who can mutually determine that they are cultural kin to one another, i.e. by identifying shared kin relations through a kinship terminology. Kinship terminologies are cultural constructs (Parkin, 1997; Read, 2001); hence the people we identify as our relatives are culturally specified and can include non-genetic kin, who only bear an indirect relationship to biological kin relations. Kinship terminologies differ from one society to another in a manner analogous to differences between languages, making conceptual distinctions in one terminology that need not be matched in another kinship terminology. Hence, the way in which one society is socially structured via cultural kin relations need not have its counterpart in another society.¹¹

2.3.1 Four Cognitive Capacities

The evolutionary pathway of our hominin ancestors necessarily starts with cognitive changes introduced or elaborated through Darwinian selection. The decoupling arises because subsequent consequences of those cognitive changes made it possible to construct social relations between individuals independent of biological kin relationships. The cognitive changes are four-fold: (1) a concept of ‘self’, (2) a “theory of mind”, (3) categorization based on the concept of a relation between individuals and (4) recursive composition of relational categories. We first briefly indicate what is meant of each of these cognitive properties and the extent to which their precursors can be found among the non-human primates. Then we consider in more detail how (3) and (4) made it possible to construct conceptual relations between individuals that can be organized into a computation system that serves among other things as a means for identifying a group of individuals that form a community through enculturation.

(1) The “concept of self” implies cognitive awareness of one’s own existence, or identity, in contrast to the existence of others. It entails that seeing an image of oneself is cognized as a representation of oneself, and not of a conspecific. To test whether non-human primates have a concept of self, researchers have placed a mark on a target individual and then registered whether the individual responds to the mark upon seeing her/his image in a mirror. If it does so by attempting to touch its location, it is assumed that the individual is linking properties seen in the image with those of his/her own body. Based on this criterion, some of the pongids, such as chimpanzees, have a concept of self, but their evolutionary precursors, the Old World monkeys, do not. As experimental evidence for a concept of self is substantial for the chimpanzees, we assume that a concept of self was already present in a primate ancestor common to chimpanzees and hominins.

food sharing occurs and the relationship between giver and receiver. These two examples should just be viewed as illustrating the qualitative difference in food sharing among primates versus human groups.

¹¹ Not all kinship terminologies are unique. Unrelated societies can have identical kinship terminologies.

(2) Having a notion of a “theory of mind” means not only that one has awareness of one’s own properties, whether they be physical, behavioral, or cognitive, but that one is able to conceptualize that other conspecifics may also have the same properties or mental representations. In particular, when an individual is aware, for example, of its own actions in response to external stimuli, then upon seeing another individual act in a similar manner under the same circumstances, the first individual can conceptualize that the other is doing so for a similar reason. Experimental work with human infants has established that a theory of mind is in place in humans by around 3–5 years of age (Hughes, 2004). But whether any of the non-human primates have a theory of mind is less clear. There is no evidence for a theory of mind among any of the Old World monkeys. Some have argued that experiments with chimpanzees show behavior patterns consistent with a theory of mind (Povinelli, Nelson, & Boysen, 1990; Premack & Woodruff, 1978; Woodruff & Premack, 1979), though others (e.g., Savage-Rumbaugh, Rumbaugh, & Boysen, 1978; Tomasello, 1998) have challenged that interpretation. Given this uncertainty, we assume that even if the common ancestor for the chimpanzees and ourselves did not have a theory of mind, the cognitive ability to do so most likely arose early during hominin evolution, so we will assume that a theory of mind is already in place among our hominin ancestors.

(3) The next cognitive capacity of concern is *categorization of relations between individuals*. Category formation with respect to *properties* of phenomena external to an individual is virtually ubiquitous among organisms, though the means by which it occurs may vary from cognitive to chemical. At some point, though, this capacity is extended to categorization based on *relations between pairs of individuals*. Recent work in primatology has begun to document the importance of such categorization as a causative factor in social behavior: “The individual model has therefore been replaced by a relational model. . .” (de Waal, 2000: 588). Correspondingly, categorization by non-human primates may possibly incorporate categories based on relations and not just properties of objects or individuals. However, the cognitive capacity to conceptualize a category of relation such as “mother” or “daughter” will arise only if the capacity is biologically grounded and a positive fitness benefit accrues from behaviors associated with the categorization. For this to be the case, the behaviors need to be directed towards one’s biological kin. Hence the category of relation that is being conceptualized also needs to be biologically accurate.

The extent to which categorization based on relations occurs among the non-human primates is unknown except for one experiment with long-tailed Macaques showing that they are capable of categorization based on biological mother/offspring and sibling relations (Dasser, 1988a, 1998b).¹² We recognize that the small number

¹² For the mother/offspring experiment the target macaque was primed with pictures of biological mother/daughter pairs. When presented with a choice between pictures of a novel biological mother/child pair and a biological mother/non-child from the same troop, the target macaque consistently (12 out of 12 trials) selected the biological mother/child pair. Similarly, when presented with a novel female and prompted to select between that female’s offspring or a non-offspring the primed macaque almost always selected the former (18 out of 20 trials). The experimenter writes:

of trials, the absence of other experiments that replicate these results, and the fact that only two out of many trained individuals responded in this manner (Cheney & Seyfarth, 1999) imply the evidence of the ability of macaques to form categories on the basis of the biological mother/offspring relation (rather than, for example, on the basis of individual characteristics of behavior between a female and her offspring), is suggestive only and not definitive. For our purposes, therefore, we will use the experimental results to suggest *only* that the ability to categorize on the basis of a relation, even if on a sporadic basis, may already be present in the early ancestry of the hominins.

The trend towards individuation may play a role in a shift towards categorization based on relations, as increased individuation decreases the likelihood that different individuals will have similar behaviors, hence making it more difficult to categorize on the basis of behavioral features. When different female/offspring pairs engage in the same behavior, for example, categorization could be based on the behavior and not the relation. With increased individuation and greater novelty in behavior on the part of a female/offspring dyad, categorization, if it occurs at all, should increasingly be based on the relation, as the relation may be the only constant factor across the instances of biological mother/offspring pairs. Hence, we posit that the trend towards increased individuation also increased the likelihood that categorization would take place on the basis of the relation between pairs of individuals. That this kind of categorization did arise eventually among our hominin ancestors is not in question, as it is the basis for the cultural kinship systems that arose sometime in our hominin ancestry; the only uncertainty is when and under what conditions the capacity arose.

(4) The last cognitive capacity, namely *recursive reasoning*, does not occur among the non-human primates (Hauser, Chomsky, & Fitch, 2002). Even the simpler cognitive task of learning a phase-structure grammar is beyond the capacity of non-human primates such as the tamarins (Fitch & Hauser, 2004). Experimental work on chimpanzees (Spinozzi, Natale, Langer, & Brakke, 1999) demonstrates clearly that regardless of their ability to work with, and attribute meaning to, symbolic representations, and regardless of the extent to which chimpanzees may have the cognitive capacities that are the precursors for language ability, they lack the cognitive capacity to reason in a fully recursive manner. The inability of chimpanzees to reason recursively may relate to the fact that their short term working memory capacity is too small for recursive reasoning (Read, 2006).

This recursive capacity relates to the ability to form a composition of relations and thereby to generate a new relation through recursion. To illustrate, let the two-place predicate $M(-, -)$ represent the biological mother/biological daughter relation defined over a set of biological individuals, S , so that, for all x, y in S , $M(x, y)$ is true when, and only when, y is the biological mother of x . We can define a new relation, MM , by the two-place predicate $MM(-, -)$, where $MM(x, z)$ is true if, and only if there is a y in S for which $M(x, y)$ and $M(y, z)$ are both true. The relation MM may

“Mother-offspring pairs were differentiated from any other pair . . . cues other than the relation between individuals do not plausibly account for the result” (Dasser, 1988b: 91).

be constructed recursively from the relation M as follows. Since there is a single y for which $M(x,y)$ is true, let $y = M(x, -)$, hence we can think of y as the outcome of applying the predicate $M(x, -)$ to the set S . Similarly, we can let $z = MM(x, -)$ when $MM(x,z)$ is true since there is a single z for which $MM(x, z)$ is true. Then $z = MM(x, -) = M(y, -) = M(M(x, -), -)$, hence MM can be reconstructed recursively by applying the M relation to the outcome of the M relation. (This form of recursion is the basis for genealogical tracing via the mother/offspring relation that we will discuss in the next section).

Even if non-human primates apparently are not capable of this type of conceptualization, the mental capacity to conceptualize recursively did arise at some point in hominin evolution. Since it is a biologically grounded capacity, there must have been a fitness benefit for it to arise in the first place. Undoubtedly the development of that capacity does not refer to any single event but rather to a series of cognitive changes. Though languages of modern *Homo sapiens* make extensive use of recursion, the capacity for recursive thinking may also have arisen as part of non-linguistic activities such as tool making (Read & van der Leeuw, 2008), and then exapted as part of the development of linguistic capability. Precursors for recursive thinking can be seen in hominin stone tool making (but not pongid stone tool use such as nut-cracking), where an action such as the technique of flake removal from a stone object is done repeatedly. Each subsequent flake removal repeats the same action on the object produced from the previous step.¹³ Regardless of the specific trajectory that led to the cognitive ability to engage in recursive thinking, such a pathway was followed during hominin evolution. We are here dealing with what may have occurred during hominin evolution after recursive thinking is already in place.

2.3.2 Theory of Mind and Recursion

We begin the pathway from biologically framed to non-biologically framed evolution by assuming that we have a set of individuals, S , with the four cognitive properties we have just discussed. For the sake of illustration, we will focus on a single relation, namely the M (“mother”) relation, but the argument applies to any relation that has become the basis for a categorization of dyads among the individuals in S . For the reasons discussed, we assume that the M relation is initially based on

¹³ Some of these changes may have been triggered by selection for the cognitive ability to make more effective and efficient stone tools. Tools made by our hominin ancestors have varied in conceptual complexity from one-dimensional (e.g., an edge, which typifies stone tools dating about 2 million years ago) to three-dimensional (e.g., blade making in the Upper Paleolithic) conceptual control over the process of stone working (Pigeot, 1991; Read & van der Leeuw, 2008; van der Leeuw, 2000). For example, the making of tools from Upper Paleolithic blade cores, Middle Paleolithic disc cores, and Middle and Lower Paleolithic Levallois cores and bifaces involves a recursive technology, but the earlier one-dimensional and two-dimensional technologies of the Oldowan (beginning c. 1.7 mya) were iterative but not recursive. This development from iterative to recursive technologies provides evidence for a time range within which the cognitive elaboration of recursive reasoning was introduced through selection for an increase in hominin working memory.

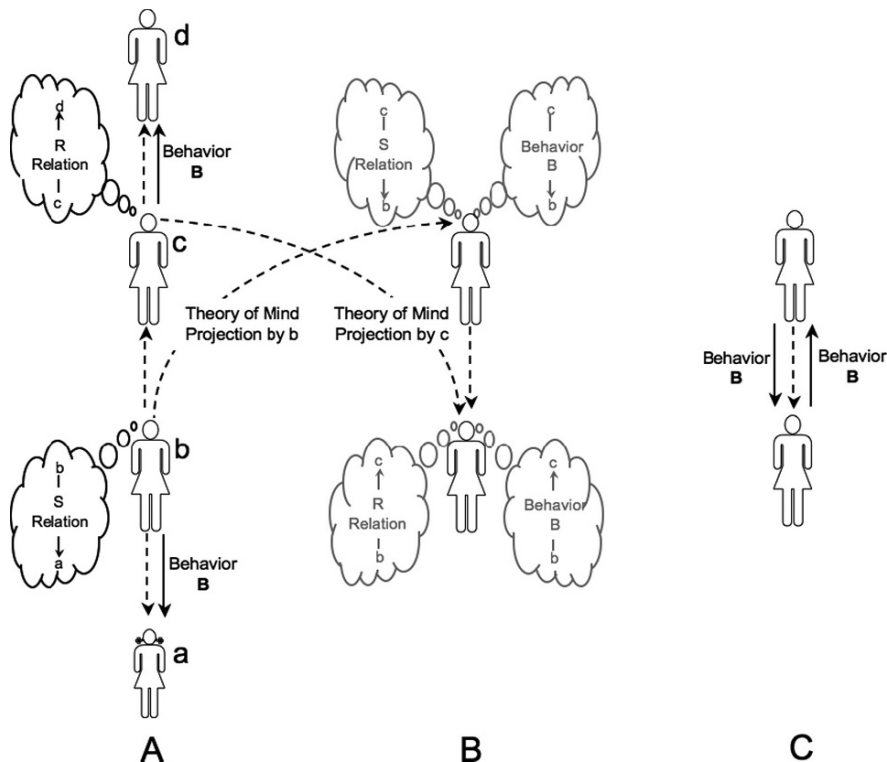


Fig. 2.8 (A) Individual *a*, biological daughter of *b*, conceptualizes a mother relation and (B) projects, via the Theory of Mind, the same relation concept to her biological mother *b*. (C) By composition of relations, individual *a* constructs a relation linking her to individual *c*, the female *a* believes to be the target of the mother relation she has attributed to *b*

categorization of actual biological mother/offspring relations. In Fig. 2.8(A), female *a* is the biological daughter of female *b*. We assume that as the daughter perceives that she and her biological mother are a dyad, she conceptualizes an instantiation of the *M* relation between herself and her mother. This is indicated by the “thought cloud” in Fig. 2.8. By virtue of the Theory of Mind, she believes that her mother also instantiates the same *M* relation between herself, *b*, and a female *c* perceived by *a* to be the biological mother of *b*. Thus the (*b*, *c*) dyad is believed by *a* to be an instantiation of the *M* relation perceived by her mother, *b* (see Fig. 2.8B). From the perspective of *a*, this instantiation is a belief since *a projects onto her mother her own belief* that her mother also perceives an *M* relation. The thought cloud in Fig. 2.8B for female *b* is dashed and in gray to indicate that this is the relation that *a* believes (correctly or not) is held by her mother.

By recursion, *a* can now construct the *MM* relation that instantiates her relationship with female *c* (see Fig. 2.8C). It differs in a crucial way from the *M* relation: it is constructed from the *M* relation through recursive reasoning and not

from categorization of actual “biological grandmother/biological granddaughter” dyads. Instead, categorization is a *consequence* of the new relation built on recursive reasoning, and categorization thus encompasses all those instances where, by virtue of the Theory of Mind, *a* projects onto another individual the relation *MM*. In other words, following the Theory of Mind, if individual *a* has constructed an *MM* relation instantiated by the (*a*, *c*) dyad, then individual *a* can project that *MM* relation onto other individuals and perceive other dyads as instantiations of the *MM* relation. Thus, the *MM* relation is not based on the biological relation of individual *c* to individual *a*, but on what individual *a* *believes* to be the case about the relation of *c* to *b*. That belief may be erroneous, but that does not affect the construction of the *MM* relation since there is no external reality against which the construction can be falsified. *Recursion of relations leads to decoupling of constructed relations from the biological basis for conceptualizing the relations involved in forming the constructed relations.*

2.3.2.1 Reciprocal Relations

From the perspective of the mother (*b*), *a* will be in a biological daughter relation *D* with respect to *b*. If *b* perceives both an *M* relation with *c* and a *D* relation with *a* (see Fig. 2.9A), and projects the *D* relation onto *c* (see Fig. 2.9B), then *b* will simultaneously be an instantiation of the projected *D* relation. Hence, *b* will

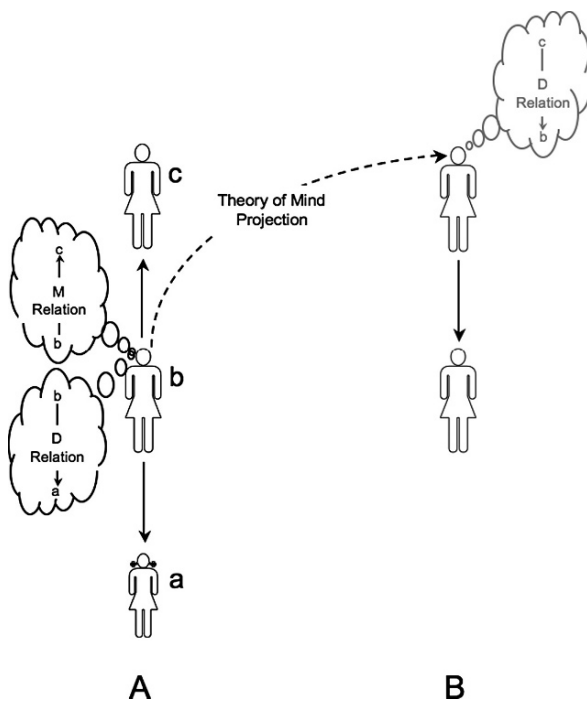


Fig. 2.9 (A) Individual *b* conceptualizes an *M* (mother) relation to *c* and a *D* (daughter) to *a*. (B) Individual *b* attributes the *D* relation to *c*, hence *b* believes that *c* has *b* as a target for the *D* relation, a precursor for a reciprocal social relationship from *b*'s perspective

perceive not only that b has an M relation to c , but also that c perceives a D relation from c to b . Consequently b will believe that b and c are conceptually linked to each other. Hence the precursor for a reciprocal social relation from b 's perspective, namely that b not only perceives a relation with c , but *also* believes that c perceives a reciprocal relation with b , is in place.

The same kind of pattern may arise with any relation R that b has with c and the corresponding reciprocal relation S that b may believe to have with a . The projection of the relation S onto c will have b as an instantiation of that relation from b 's perspective, and so b will perceive that b has a relation R with c and will believe that c perceives a relation S between c and b , regardless of what is the actual biological relation of c to b .¹⁴

2.3.3 *Functionality of the Projected Relation*

Just as with kin relations, where the evolutionary importance lies not in the biological kin relationship *per se*, but in a biologically based behavior associated with the biological relation, the importance of perceiving a relation R lies not in the relation *per se*, but in behaviors and/or motivation for behaviors that can be associated with the relation, and that lead to social interaction. Following Talcott Parsons (1964: 5), we distinguish here between interaction and *social* interaction:

It is a fundamental property of action thus defined that it does not consist only of ad hoc 'responses' to particular situational 'stimuli' but that the actor develops a *system* of 'expectations' relative to the various objects of the situation. These *may* be structured only relative to his own need-dispositions and the probabilities of gratification or deprivation contingent on the various alternatives of action that he may undertake. **But in the case of interactions with social objects a further dimension is added. Part of ego's expectation, in many cases the most crucial part, consists in the probable reaction of alter to ego's possible action, a reaction which comes to be anticipated in advance and thus to affect ego's own choices** (Italics in the original, bold added).

Parenting is an example of interaction that need not involve *social* interaction since a may engage in parenting behavior towards b by virtue of being a parent and without any necessary expectation of reciprocal behavior. Or, from the perspective of the child b , b has expectations about how a will act (feed, comfort, etc.) regardless of how b might or might not perceive his or her interaction with a . In general, behavior such as altruism introduced through selection based on biological kinship *is not social if there is no anticipation that the behavior will be reciprocated* in some manner. But behavior based on cultural kinship *is social* as the conceptual system that

¹⁴ The relation R could be "is a friend" or "is an ally" given the evidence that non-human primates modify behavior on the basis of the relationship between the two individuals in a dyad (reviewed in Silk, 2003). However, a constructed relation such as "is a friend of a friend" would presumably imply an expectation of friendly behavior on the part of the individual so identified, and the validity of the constructed relation for behavior may thus be subject to empirical verification – in contrast to a constructed relation such as "mother of a mother."

structures cultural kinship (the kinship terminology) is based on reciprocal relations and expected reciprocal behavior. If a recognizes b as a cultural kin then the kinship relation entails that a also recognizes that a is a cultural kin from b 's perspective by virtue of the reciprocal property of the kinship terminology. Therefore a can expect reciprocal behavior on the part of b .

To activate a social relation between a and b depends, then, on some understanding by a and b that they are at least conceptually linked to one another.¹⁵ Otherwise, there is no reason to expect reciprocal behavior. For kin-based societies (e.g. hunter-gatherer societies), there cannot be a social relation between individuals a and b unless they have first established that they are (cultural) kin – which means that they are both part of each other's conceptual domain, and have acknowledged it. An extreme example of this is the fact that, in the past, among the Waorani in South America, if a person b , came to a 's village and b did not have a kin relation with a , then the matter of determining whether a social relation is possible was resolved by a killing b (Davis & Yost, 2001).

Theory of Mind projections may trigger any kind of behavior that one individual might engage in vis-à-vis another if it is connected with a relation R between the two individuals. If b has a relation R with c , and a reciprocal relation S with a , and the biological relations among a , b and c are indeterminate, then b may exhibit behavior B towards any individual that is a target of the relation S conceptualized by b (see Fig. 2.10A). If b also projects the relation S and the associated behavior (B) onto c (see Fig. 2.10B), b believes that c will reciprocate with behavior B since she/he is a target of the relation S that b believes to be held by c . Then, b may engage in the same behavior towards c in the belief that c will reciprocate with that behavior (see Fig. 2.10C). We now have a basis for interaction to become social interaction: *one individual acts towards another individual under the belief that the other individual will act in a reciprocal manner. Further, and critically, this basis for social interaction is decoupled from any requirement of biological relations among the individuals in question.*

2.3.4 Mutual Recognition as a Basis for Social Interaction

While the projection of a behavior linked to a relation may lead to the belief that such behavior will be reciprocated, such reciprocal behavior need not actually occur unless the other individual has constructed a complementary belief system and behaves accordingly. Cheating, used here in the sense that the behavior is not initiated despite having the complementary belief system, is always possible and if b acts

¹⁵ A conceptual linkage between individuals is not a necessary pre-requisite for social interaction. Social interaction can arise from genetically based behavior if the selection for the behavior by a is correlated with possible responses by b . In probabilistic terms, non-social interaction would be a behavior B where the unconditional probability of a doing B in the presence of individual b is the same as the conditional probability of a doing B knowing that b does some behavior B' .

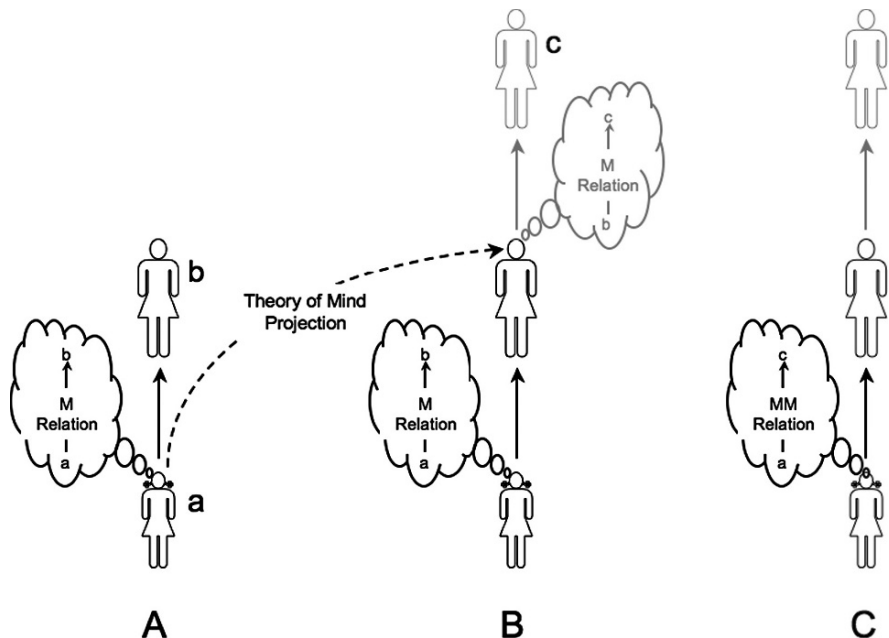


Fig. 2.10 (A) Individual *b* conceptualizes a relation *R* with *c* and a reciprocal relation *S* with *a*. In addition, *b* directs behavior *B* towards individual *a* when *a* is the target of the *S* relation conceptualized by *b*. (B) Individual *b* projects relation concept *S* to individual *c* and *b* is the target of the relation *S* believed by *b* to be a relation concept held by *c*. (C) Individual *b* directs behavior *B* towards *c* due to *b*'s belief that *b* is a target of the *S* relation held by *c*. That is, *b* believes *c* will direct behavior *B* towards *c* since *b* directs behavior *B* towards *a* due to *b*'s relation *S* with *a*, hence *b* expects *c* to direct behavior *B* towards *b*

towards *c* simply under the *belief* that *c* will reciprocate, then *b* has actually initiated conditions that favor cheating by *c*.

Actual, as opposed to potential, social interaction depends upon engaging in reciprocal behaviors. If both parties believe that the other will reciprocate, then the foundation for continued social interaction will have been laid. For this to occur, it suffices that *c* associates behavior *B* with the relation *R* and *b* associates the same behavior with the reciprocal relation *S*, as shown in Fig. 2.11.¹⁶ Under these conditions, both *b* and *c* will independently construct the belief the other will reciprocate with the behavior *B*. When each individual, based on his or her own beliefs, then engages in behavior *B* towards the other, the beliefs are reinforced by the actual behavior of the other individual.

This argument has two important implications. First, the pool of individuals who have the reciprocal belief system illustrated in Fig. 2.11 will increase if the behavior *B* is associated with both the relation *R* and its reciprocal relation *S*. When the

¹⁶ For the sake of clarity, the reciprocal relations have not been drawn for each of the individuals *b* and *c*.

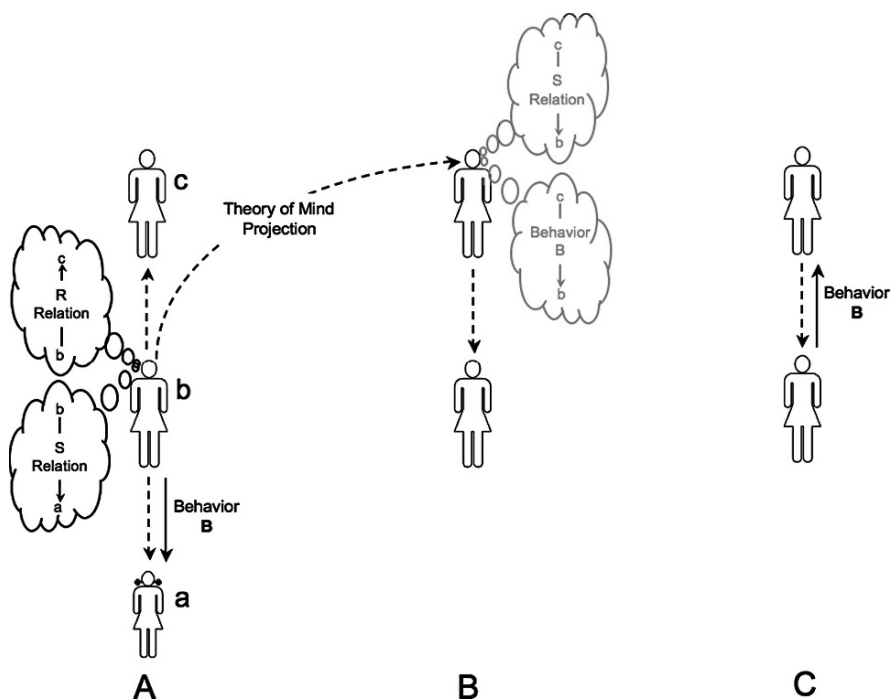


Fig. 2.11 (A) Individuals *b* and *c* each share the same conceptual pair of reciprocal relations (only one relation from each pair shown for clarity) and each associates] behavior *B* with a relation, with individual *c* directing behavior *B* to individual *d* and individual *b* directing behavior *B* to individual *a*. (B) Each of *b* and *c* projects their conceptual relations onto the other individual. (C) Each of *b* and *c* directs behavior *B* towards the other individual on the basis of one's belief that the other individual will reciprocate with *B* or *B*-like behavior. The beliefs of both *b* and *c* are reinforced by the behavior of the other individual

behavior is associated with both these relations for *b* in Fig. 2.11, then when *b* interacts with *c* it will be irrelevant whether *c* only associates the behavior with *R*, or only with *S*, or both. In any of these situations the conditions for arriving at Fig. 2.11C are satisfied. Translated into cultural kin relations, this means that a behavior will be associated with the kin relation *R* and the reciprocal kin relation *S* if whenever ego engages in a behavior *B* with respect to someone in the kin relation *R* to ego, then ego is equally willing to engage in that behavior with respect to someone in the reciprocal kin relation *S* to ego. For example, if ego as an adult engages in cooperative behavior towards his/her children, then ego should equally engage in cooperative behavior towards her/his parents since the parent-kin relation is the reciprocal for the child-kin relation.¹⁷

¹⁷ This differs from what would be predicted under biological kin selection with inclusive fitness for adults. Even under inclusive fitness there is little or no direct fitness benefit to be gained by directing even cooperative behavior towards parents instead of towards one's offspring.

Second, to realize the functional benefit of reciprocal behaviors, individuals must recognize the kind of relation with which a behavior is associated in comparable ways. Agreement between actor and recipient with respect to enactment of a behavior requires that both the actor and the recipient associate it with the set of reciprocal relations between them. The likelihood that that occurs depends on the degree of coordination among group members with regard to the relations they recognize and the behaviors associated with them. This, in turn, requires a role system for the patterns of behavior engaged in by individuals.

The coordination problem is thus solved through enculturation involving kinship terminologies by virtue of the fact that the system of kinship terms (1) is a computation system through which kin relations may be calculated in a simple manner, (2) is a generative computation system, and (3) implies that reciprocity for all kin relations follows from reciprocity of the generating kin relations.

By a computation system is meant that two individuals a and b can determine the kin relation they have to each other when there is a third individual, c , and a and b both know their relation to c via the kin terms they each use to refer to c :

... [Maori 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*, whereas 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: 155, emphasis added).

The computation system is generative in the algebraic sense that there is a subset of the set of kin terms from which all other kin terms can be generated through use of (a) the binary product for kin terms and (b) a set of structural equations based on just the generating kin terms. Empirically, the kin terms serving as generators refer to family relations. For some terminologies, the terms that express the mother and father relations are the generators; for others, the terms expressing the brother and the sister relations are also generating terms. The latter terminologies have very different structural properties than those for which the terms expressing the brother and sister relations are not generators (Bennardo & Read, 2005; Read, 2001).

Reciprocity of kin terms follows from reciprocity of the generating kin term relations. It means simply that when, say, the mother relation is conceptualized, then the relation from her to her offspring is also conceptualized, or when the sister relation is conceptualized, then the reciprocal sibling relation is also conceptualized. Hence just knowing another person is one's cultural kin is a sufficient basis for social interaction as defined by Talcott Parsons and the set of persons who can mutually recognize each other as cultural kin can form a social system that does not depend on prior face-to-face interaction to adopt appropriate behavior towards one's cultural kin that will likely be reciprocated.

The fact that individuals can compute on the fly whether they have a cultural kin relation implies that the size of the group of socially interacting individuals is limited by the connectedness of mating/marriage networks. Pragmatically, the limit appears to be about 500 individuals, the modal size of hunter-gatherer groups independent

of ecological, climatic, and other environmental conditions and independent of the relative abundance or scarcity of resources. The modal 500 individuals typically do not form a single residence group but are subdivided into smaller residence groups in a manner consistent with resource distribution and methods of resource procurement, yet they maintain coherence as a system of socially interacting individuals through the kinship system expressed through the kinship terminology. Transmitting the cultural kinship computation system as well as associated appropriate behaviors depends on developing children interacting with enculturated adults engaging in those behaviors, who perceive that the children's well-being depends upon their being enculturated with the knowledge that these are behaviors to be directed towards one's kin.

The remaining piece of the evolutionary pathway to be worked out concerns the reasons why a computation system for cultural kin relations should have a generative structure. In theory, composition of relations could simply be carried out for two or three products and no more, or some potential products might simply not be recognized. But in reality, a kinship computation system is logically consistent and can be modeled isomorphically as an algebra (see, for example, Bennardo & Read, 2005).

2.3.5 Cross-Generational Decay of the Functionality of a Set of Relations

We now assume that we have a set S of conceptual relations and an associated set of reciprocal conceptual relations, R , along with a set B of behaviors that are part of the repertoire of a cohort of socially interacting individuals. We assume (1) that some functionality, f , is obtained from the behaviors as a consequence of the shared set of relations, S . We further assume (2) that the total functionality, f , that can be obtained from the behaviors associated with S varies directly with the number of relations in S , which determines the size of the network of interconnected individuals, and (3) that the larger the network the greater the total functionality, f , that can be obtained from interaction among the individuals. But the functionality is subject to an upper bound due to resource constraints (given the mode of resource procurement), and organizational stress (given the mode of societal organization¹⁸).

However, not all individuals connected via relations in the set S will also be individuals for whom the conditions of Fig. 2.10 apply, so we need to distinguish between the potential functionality that is based on the size of S and the actual functionality based upon the actual pattern of interaction among the connected individuals. In mathematical terms, the number of relations in the set S is the cardinality of the set S . Let us refer to f , the functionality associated with S , as the *potential*

¹⁸ The constraints identify conditions under which evolutionary change in either the mode of resource procurement or the organizational structure can occur via cultural group selection as discussed below.

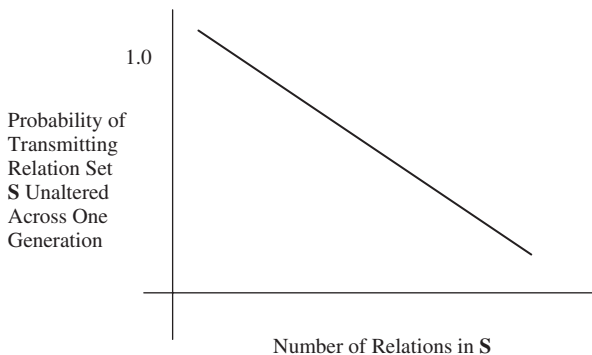
functionality of the set S . It will vary with the cardinality of S . The *actual functionality*, f^* , of S will depend upon the number of co-ordinated individuals in the cohort C . Individuals a and b are coordinated (see Fig. 2.11) if whenever individual a perceives a relation R between a and b with associated behavior B , then individual b perceives the reciprocal relation S between b and a with associated behavior B' . Coordination is thus a consequence of enculturation.

Cohort C will change membership through time due to demographic effects, and to maintain the same functionality, f^* , the new members of the cohort must learn the relations in S and the categories of persons associated with these relations. However, the probability of the set S being transmitted without loss or alteration of content from one generation to the next decreases with the cardinality of the set S (as is shown schematically in Fig. 2.12). Consequently, the actual functionality f^* associated with the set S will decay through time and the greater the cardinality of the set S , the more rapid the decay.

2.3.5.1 Syntactically Organized Versus Syntactically Unorganized Sets of Relations

The decay due to transmission arises from the number of distinct and independent relations that need to be learned.¹⁹ For some relation sets, each relation must be transmitted, for example, when the probability that relation S is in the set S cannot be determined from a subset of S that does not contain S . In such cases, the number of relations that need to be learned is the same as the cardinality of the set S . For other relation sets it is possible to predict the occurrence of a relation S from a subset of S because the set S is *syntactically organized*, i.e. there is a set of rules and initial conditions that suffice to generate the full set of relations from a set of generating relations that is a proper subset of S . When this is the case, then just the rules and

Fig. 2.12 Schematic graph showing a declining probability of faithfully transmitting a set of relations from one generation to the next



¹⁹ It is important from our perspective that there is a qualitative difference between non-human primates and humans, in that humans easily infer simple finite state and phrase-structure grammars, but primates such as the tamarins can only infer patterning in the form of a finite state grammar and not a phrase-structure grammar (Fitch & Hauser, 2004).

the generating relations need to be transmitted. For example, if S consists of the relations $\{M, MM, MMM, MMMM\}$, then one only needs to transmit the relation M , the rule $x \rightarrow xM$, (where x is either M or the output of the rule), and the constraint that the rule can only be applied to strings of length < 4 . If the rules are simple enough to be transmitted faithfully, the relation set will be transmitted faithfully and there will be no loss in the functionality through time (see Fig. 2.13). The decrease in the probability that the relation set S is transmitted faithfully when there is an increase in the cardinality of S and when S is not syntactically organized, drives the relation set S to an algebra-like structure. Due to loss of functionality through transmission error, we can therefore expect change in the content of S to continue until S has a syntactically organized configuration (an algebra-like structure²⁰).

Relations (by virtue of the fact that they may be composed to form new relations) allow a simple syntactic organization consisting of an indefinitely large set of relations S that is generated from a limited set of rules. The generating relations, M , F , S and D (i.e., Mother, Father, Son and Daughter) and the recursive generative rule: “If x and y are either generating relation or the outcome of this rule, then xy is also a relation” generate an infinite set of relations that includes all of (and more than) the relations involved in genealogical tracing from one individual to another.²¹

A rule-based system of genealogical relations not only reduces the likelihood of transmission error, but also provides a way to correct transmission errors due to (a) incorrect calculation of the rule or (b) transmission errors due to direct transmission of relations (rather than through inference from the set of rules and generating relations). Transmission errors can be corrected through majority agreement on the set S as long as the likelihood that a majority of individuals all simultaneously learn the

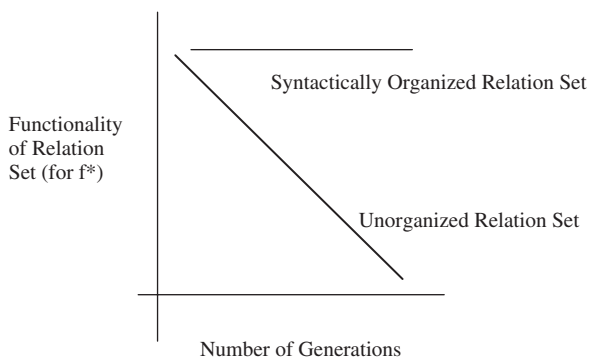


Fig. 2.13 Schematic graphs comparing fitness change for syntactically organized versus unorganized sets of relations

²⁰ The likelihood that there will be faithful transmission can undergo something like a phase transition when changes in the content of S introduce patterning in S so that it now has syntactic organization, thus enabling a switch in transmittal of S from learning each relation in S to learning a set of rules from which S can be reproduced.

²¹ Genealogical tracing is usually limited to either tracing up only, tracing down only, or tracing up and then tracing down. More complicated tracing patterns such as tracing up, then tracing down and then tracing up are excluded from the way genealogical relations are calculated.

same error is low. We can distinguish between systematic and non-systematic errors. Systematic errors are cases in which it is erroneously assumed that a sequence of relations has a “natural” continuation (for example assuming that the genealogical tracing sequence “up, up, down, down” might be followed by two more ups, which runs afoul of the fact that “up, down, up” sequences are usually not allowed). Non-systematic errors occur for other reasons.

The probability that all novices independently make the same non-systematic errors when learning the set S is obviously very low, and individual non-systematic errors can be eliminated through consensus agreement on the content of S . Systematic errors, however, increase the likelihood that a majority of individuals all simultaneously believe that an erroneous relation occurs in the set S , so that consensus would change S to a modified form, S^* . Because a systematic error led to S^* , the set S^* may also be transmitted faithfully. Hence, a form of evolution has taken place, but one that is neither a Darwinian fitness-based evolution, nor a dual inheritance form of evolutionary change. Rather, the evolution from S to S^* has been driven by a change in the set of relations that maintains (or possibly even increases) the likelihood that the set S^* is transmitted faithfully.²²

2.3.5.2 Organizational Implications

Faithful transmission of the conceptual system that underpins its organizational structure is, of course, necessary for organizational continuity in a population. But the fact that the functionality of the system depends upon the social interactions enabled by the relation set complicates our understanding of change during the transmission process. In a Darwinian evolutionary framework, an individual’s conceptual system and cognitive repertoire would have to be included in the person’s phenotype, and we would consider change in the frequency of people with that relation set as due to the manner in which it is transmitted. That approach has two serious flaws.

²² Evolutionary change can also take place when a difference in the decay rates of sets of relations will lead to a difference in the rate of loss of functionality obtained from a relation set. Suppose we have two populations with relation sets S and T in competition (in the Lotka-Volterra sense) over resources. Assume (1) that the (potential and actual) functionality is initially the same for both sets of relations, (2) that the respective carrying capacities of these populations relate directly to the functionalities obtained from their relation sets, and (3) that the competition parameters are such that the two populations are initially in equilibrium. Then, if the decay rate of relation set S is slow compared to the decay rate of set T , the population with set T will find the functionality obtained from its relation set, and thus its carrying capacity, decreases more rapidly than is the case for the other population. If the reductions in carrying capacity are proportional to the rates of decay of the relation sets, then the population with the slower rate of decay of its relation set will win out in competition with the other population. But because the decay rate for a set of relations S is, at least in first approximation, determined by the cardinality of S , and not by the functionality f^* of S , evolutionary changes in functionality caused by differences in decay rates will not be driven by Darwinian fitness since the differences in decay rates are not themselves due to differences in Darwinian fitness but to the cardinality and syntactical organization of a set of relations.

The first, already noted, is the assumption that we are dealing with individual traits, whereas because the functionality arises from a relation set, we must consider a dyad to be the minimum unit. The second flaw is that the functionality accruing to an individual arises from a network of socially interacting individuals, and is not an individual property. It arises from the consequences for an individual of the organizational structure encoded in the conceptual system.

As discussed in Section 2.2, transmission of the organizational structure for a population via enculturation is not simply the sum of trait transmission among individuals. Once a conceptual basis for an organizational system is established, it is maintained by the fact that individuals are born into an ongoing system of enculturated individuals that have, from birth, operated in accordance with the organizational system. Hence, the new-born become enculturated with that system. In large-scale social systems, enculturation need not be uniform across all individuals (see Fig. 2.4); instead enculturation may be regional in scope, but the difference is one of degree and not of kind. It is difficult to see how individuals, except under extraordinary circumstances, could not, to one degree or another, be enculturated in the conceptual system underpinning the society in which they are born and raised.

Organizational systems, as a whole, become larger or smaller as a consequence of demographic changes, including recruitment. The magnitude and form of demographic changes relate to the functionality of the organizational system, hence the changes are due to group properties rather than individual properties and their associated relative fitness values. Variation in individual fitness values, while affecting the frequency distribution of individual traits linked to them, does not determine the demographic trajectory of a population and its organizational system.

2.4 Conclusions

The cognitive evolution we have outlined begins, as it must, as Darwinian evolution driven by individual fitness and extended through biological kin selection and inclusive fitness to behaviors of interacting biologically related individuals. We have argued that the introduction of relational concepts based on categorization of dyadic interactions into the conceptual repertoire of individuals, in conjunction with the cognitive capacity to form recursively defined compositions of relations, had the effect of decoupling the emerging system of conceptually formed categories of relations from its foundation in behavior among biological kin. But the importance of this shift lies not just in what became conceptually possible once the cognitive capacity for recursive reasoning was in place, but also, if not primarily, in the functionality that was thereby obtained. One aspect of that functionality is the manner in which behaviors could now be associated with relational concepts, hence allowing for the extension of kinds of behavior (e.g., co-operation, altruism, reciprocity) otherwise restricted to interaction between biological kin to distantly related (or even non-biologically related) individuals on the basis of the conceptual relation that links

them. To achieve this functionality, though, the conceptual system must be shared by the individuals involved.

What our hominin ancestors worked out, then, was not simply an elaboration on the form of social organization that characterized our common ancestor with *Pan*, our closest non-human primate relative, but social organization based on an entirely different modality. The shift, we have argued, is from social organization based primarily on reproductive and/or individual learning/imitation transmission to social organization based on enculturation transmission of a conceptual system in which relations among societal members are worked out (even though it may draw upon properties transmitted through reproductive transmission or individual learning/imitation transmission). Thereby, the properties of the social system became decoupled from its genetic foundations. The transition assumes Darwinian evolution led to the cognitive capacity for constructing a system of conceptually based social relations. Once in place, the subsequent shift in the basis for social organization gave rise to further evolutionary change driven by the need for social organization to be understood in essentially the same manner by each of the society's members. Change in the basis for social organization supplemented evolution driven at the individual level by an evolutionary process that is not driven by properties of individuals as individuals. This change causes functionality to arise from the form of social organization and the behaviors of individuals *as part of their social system*. Whereas behaviors are seen as the driving force for social organization based upon individual learning/imitation, the social organization and the conceptual system(s) upon which behaviors are based become a driving force for an increasingly complex behavioral repertoire whose transmission among community members was enabled by enculturation. Enculturation transmission can incorporate the increasingly elaborated conceptual dimensions discussed by van der Leeuw et al. in Chapter 3.12 that are the basis for our interaction with the material world through our production and use of artifacts. It can also encompass innovation in information processing and in forms of communication central to evolutionary changes in the scope and complexity of human social organization that are detailed in that chapter.

Reproduction transmission concerns the *implications of individual change for summary population properties*, where the population is determined by the mating patterns leading to reproduction. In contrast, enculturation transmission concerns *the implications social groups have for individuals* by providing the context for interaction between enculturated adults and newborn offspring that leads the child to internalize an ensemble of cultural resources from among those with which s(he) is necessarily involved from birth. Enculturation enables interaction in accordance with a framework for behavior that is functional because other people share the same cultural resources. Comprehensive participation in such cultural resources is virtually a prerequisite for their functionality, and enculturation is the transmission process that enables this.

Enculturation with these cultural resources enables the formation of coherent groups of socially interacting individuals without first requiring experiential learning through prior face-to-face interaction, making social interaction among "strangers" feasible. Identification of a cohort of individuals with shared cultural

resources further depends on a cultural resource we know as a kinship terminology. It enables an individual to determine if s(he) has a cultural kin relation to another individual and vice-versa, so that both must share a wider ensemble of cultural resources individually obtained through enculturation.

Consequently, it is not surprising that the boundaries of social interaction begin with the boundaries of the group of individuals who can mutually recognize one another as cultural kin.²³ The social group thereby was freed from the constraints imposed by the conditions that individual learning through face-to-face interaction impose on social interaction (or the constraints of highly structured mating systems for social interaction to be based on genetically transmitted behaviors). In this manner, a social group can take on functionality far exceeding the forms of social organization available to the non-human primates. New functionality could now be introduced through change in the organizational basis for societies, as expressed through change in cultural resources and tested through cultural group competition (Read, 1987).

Acknowledgments We would like to thank Henry Wright for comments on an earlier draft of this manuscript.

References

- Bennardo, G., & Read, D. W. (2005). The Tongan kinship terminology: Insights from an algebraic analysis. *Mathematical Anthropology and Culture Theory*, 2.
- Biersack, A. (1982). The logic of misplaced concreteness: Paiela body counting and the nature of the primitive mind. *American Anthropologist*, 84, 811–829.
- Bourgine, P., & Johnson, J. (Eds.). (2006). *Living roadmap for complex systems science*. Vol. Version 1.22.
- Boyd, R., & Richerson, P. (1985). *Culture and the evolutionary process*. Chicago: University of Chicago Press.
- Byrne, R. W., & Whiten, A. (1997a). Machiavellian intelligence. In R. W. Byrne & A. Whiten (Eds.), *Machiavellian intelligence II: Extensions and evaluations* (pp. 1–15). Cambridge: Cambridge University Press.
- Byrne, R. W., & Whiten, A. (Eds.). (1997b). *Machiavellian intelligence II: Extensions and evaluations*. Cambridge: Cambridge University Press.
- Chance, M. R. A., & Mead, A. P. (1953). Social behaviour and primate evolution. *Symposia of the Society for Experimental Biology*, VII, 395–439.

²³ Other cultural constructs that involve enculturation can give rise to similar functionality. Lane and Maxfield (2005) observe that “narrative structures are cultural facts of narrative communities . . . [and] narrative . . . rules of syntax . . . are abducted from the many stories instantiating them that circulate in the narrative community, to which members of the community begin listening as infants and continue listening, and then telling, throughout their lives” (p. 13). They consider “narrative logic [to be] a local . . . solution to the problems posed by ontological uncertainty” (p. 15) that arises, in their case study of Echelon (a Silicon-valley start-up company), when innovation is poised to replace current technology. Narration, they argue, gives the narrator “a sense of direction . . . and an understanding of his own character and that of the other actors with whom he is enmeshed” (p. 15); that is, it helps to reestablish group coherency despite the uncertainties introduced as a side effect of innovation.

- Cheney, D. L., & Seyfarth, R. M. (1999). Recognition of other individuals' social relationships by female baboons. *Animal Behaviour*, *58*, 67–75.
- Dasser, V. (1988a). A social concept in Java monkeys. *Animal Behaviour*, *36*, 225–230.
- Dasser, V. (1988b). Mapping social concepts in monkeys. In R. W. Byrne & A. Whiten (Eds.), *Machiavellian intelligence: Social expertise and the evolution of intellect in monkeys, apes, and humans* (pp. 85–93). New York: Oxford University Press.
- Davis, E. W., & Yost, J. A. (2001). The creation of social hierarchy. In R. B. Morrison & C. R. Wilson (Eds.), *Ethnographic essays in cultural anthropology* (pp. 82–120). Belmont: Thomson Publishers.
- de Waal, F. B. M. (2000). Primates – A natural heritage of conflict resolution. *Science*, *289*, 586–590.
- Dunbar, R. (1995). Neocortex size and group size in primates: A test of the hypothesis. *Journal of Human Evolution*, *28*, 287–296.
- Dunbar, R. (2003). The social brain: Mind, language, and society in evolutionary perspective. *Annual Review of Anthropology*, *32*, 163–181.
- Fitch, W. T., & Hauser, M. D. (2004). Computational constraints on syntactic processing in a nonhuman primate. *Science*, *303*, 377–380.
- Flack, J. C., Girvan, M., de Waal, F. B. M., & Krakauer, D. C. (2006). Policing stabilizes construction of social niches in primates. *Nature*, *439*, 426–429.
- Goldberg, T., & Wrangham, R. (1997). Genetic correlates of social behaviour in wild chimpanzees: Evidence from mitochondrial DNA. *Animal Behaviour*, *54*, 559–570.
- Hauser, M. D., Chomsky, N., & Fitch, W. T. (2002). The faculty of language: What is it, who has it and how did it evolve? *Science*, *298*, 1569–1579.
- Hughes, C. (2004). What are the links between theory of mind and social relations? Review, reflections and new directions for studies of typical and atypical development. *Social Development*, *13*, 590–619.
- Humphrey, N. K. (1976). The social function of intellect. In P. P. G. Bateson & R. A. Hinde (Eds.), *Growing points in ethology*. Cambridge: Cambridge University Press.
- Kottak, C. (2004). *Window on humanity: A concise introduction to anthropology*. New York: McGraw-Hill.
- Kummer, H. (1967). Tripartite relations in Hamadryas baboons. In S. A. Altmann (Ed.), *Social communication among primates*. Chicago: University of Chicago Press.
- Lane, D., & Maxfield, R. (2005). Ontological uncertainty and innovation. *Journal of Evolutionary Economics*, *15*, 3–50.
- Lee, R. (1990). *The Dobe Ju'hoansi* (3rd ed.). Toronto: Wadsworth.
- Marshall, L. (1976). *The !Kung of Nyae Nyae*. Cambridge: Harvard University Press.
- McGrew, W. C. (1992). *Chimpanzee material culture: Implications for human evolution*. Cambridge: Cambridge University Press.
- Mitani, J., Merriwether, D. A., & Zhang, C. (2000). Male affiliation, cooperation, and kinship in wild chimpanzees. *Animal Behaviour*, *59*, 885–893.
- Mitani, J. C., Watts, D. P., Pepper, J. W., & Merriwether, D. A. (2002). Demographic and social constraints on male chimpanzee behaviour. *Animal Behaviour*, *64*, 727–737.
- Morin, P., Moore, J., Chakraborty, R., Jin, L., Goodall, J., & Woodruff, D. (1994). Kin selection, social structure, gene flow, and the evolution of chimpanzees. *Science*, *265*, 1145–1332.
- Nishida, T., & Hiraiwa-Hasegawa, M. (1987). Chimpanzees and bonobos: Cooperative relationships among males. In B. B. Smuts, D. L. Cheney, R. M. Seyfarth, R. Wrangham, & T. T. Struhsaker (Eds.), *Primate societies* (pp. 165–178). Chicago: University of Chicago Press.
- Parkin, R. (1997). *Kinship: An introduction to basic concepts*. London: Blackwell.
- Parsons, T. (1964). *The social system*. New York: Free Press of Glencoe.
- Pigeot, N. (1991). Reflexions sur l'histoire technique de l'homme: De l'évolution cognitive à l'évolution culturelle. *Paléo*, *3*, 167–200.
- Povinelli, D. J., Nelson, K. E., & Boysen, S. T. (1990). Inferences about guessing and knowing by chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology*, *104*, 203–210.

- Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, 4, 515–526.
- Pusey, A. E., & Packer, C. (1987). Dispersal and philopatry. In B. B. Smuts, D. L. Cheney, R. M. Seyfarth, & T. T. Struhsaker (Eds.), *Primate societies*. Chicago: University of Chicago Press.
- Read, D. W. (1984). An algebraic account of the American Kinship terminology. *Current Anthropology*, 25, 417–440.
- Read, D. W. (1987). Foraging society organization: A simple model of a complex transition. *European Journal of Operational Research*, 30, 230–236.
- Read, D. W. (2001). What is kinship? In R. Feinberg & M. Ottenheimer, *The cultural analysis of kinship: The legacy of David Schneider and its implications for anthropological relativism* (pp. 78–117). Urbana: University of Illinois Press.
- Read, D. W. (2004). The emergence of order from disorder as a form of self organization. *Computational & Mathematical Organization Theory*, 9, 195–225.
- Read, D. W. (2005). Change in the form of evolution: Transition from primate to hominid forms of social organization. *Journal of Mathematical Sociology*, 29, 91–114.
- Read, D. W. (2006). Working memory: A cognitive limit to non-human primate recursive thinking prior to hominid evolution? *Cognitive Science Journal Archive*, 2674–2679.
- Read, D. W., & van der Leeuw, S. (2008). Biology is only part of the story. *Philosophical Transactions of the Royal Society B*, 363, 1959–1968.
- Reader, S. M., & Laland, K. N. (2002). Social intelligence, innovation, and enhanced brain size in primates. *Proceedings of the National Academy of Sciences (USA)*, 99, 4436–4441.
- Rodseth, L., Wrangham, R. W., Harrigan, A. M., & Smuts, B. B. (1991). The human community as a primate society. *Current Anthropology*, 32, 221–254.
- Sahlins, M. (1962). *Moala: Culture and nature on a Fijian Island*. Englewood Cliffs: Prentice-Hall.
- Savage-Rumbaugh, E. S., Rumbaugh, D. M., & Boysen, S. T. (1978). Sarah's problems in comprehension. *Behavioral and Brain Sciences*, 1, 555–557.
- Schwartz, T. (1981). The acquisition of culture. *Ethos*, 9, 4–17.
- Shettleworth, S. (1998). *Cognition, evolution and behavior*. Oxford: Oxford University Press.
- Silk, J. B. (2003). Cooperation without counting: The puzzle of friendship. In P. Hammerstein (Ed.), *Genetic and cultural evolution of cooperation* (pp. 37–54). Cambridge: MIT Press.
- Spinozzi, G., Natale, F., Langer, J., & Brakke, K. E. (1999). Spontaneous class grouping behavior by bonobos (*Pan paniscus*) and common chimpanzees (*P. troglodytes*). *Animal Cognition*, 2, 157–170.
- Tomasello, M. (1998). Uniquely primate, uniquely human. *Developmental Science*, 1, 1–30.
- Tomasello, M. (2000). *The cultural origins of human cognition*. Cambridge: Harvard University Press.
- van der Leeuw, S. E. (2000). Making tools from stone and clay. In P. Anderson and T. Murray (Eds.), *Australian archaeologist: Collected papers in honour of Jim Allen* (pp. 69–88), Coombs, Australia: Coombs Academic Publishing.
- Vigilant, L., Hofreiter, M., Siedel, H., & Boesch, C. (2001). Paternity and relatedness in wild chimpanzee communities. *Proceedings of the National Academy of Sciences (USA)*, 98, 12890–12895.
- Vinden, P. G. (2004). In defense of enculturation. *Behavioral and Brain Sciences*, 27, 79–151.
- Whiten, A., & Byrne, R. W. (Eds.). (1988). *Machiavellian intelligence: Social expertise and the evolution of intellect in monkeys, apes, and humans*. Oxford: Clarendon Press.
- Woodruff, G., & Premack, D. (1979). Intentional communication in the chimpanzee: The development of deception. *Cognition*, 7, 333–362.