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A Formal Explanation of Formal Explanation

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1. Introduction

A good, formal representation makes it possible to determine (mathematically) the logical consequence of hypothesized structuring processes. Those processes become explanatory for patterning found in empirical observations when we find agreement between their consequences and patterning determined through empirical observations. What constitutes patterning for social systems is complicated, though, by the way behavior is framed through cultural idea systems. Behavior is neither driven exclusively by cultural idea systems nor are cultural idea systems simply a codification of already existing behaviors. Instead, there is a complex, time-dependent interplay between action and concepts involved in action that needs to be formally represented using both models that are the consequence of the posited structuring processes and models that represent the complex pattern that arises from behavior interfacing with cultural idea systems. Cultural idea systems are not just a collection of ideas: "they are much more than just a few interrelated ideas that we can represent with formalizations if we want to. They are systems that require such representation and cannot be understood otherwise, just in the way that is true of systems of logic, mathematics or models of the atom" (Leaf 2007: 16). Observations upon which explanatory arguments are based must, therefore, incorporate both the phenomenal and the ideational domains of culture-bearers and the interplay between these domains. Implications the latter has for formal representations and explanatory arguments regarding social and cultural systems are the theme of this paper.

2. Theory Models and Data Models

Modeling, in the broad sense of delineating what are believed to be the relationships giving structure to the domain of inquiry or study, is implicitly, if not explicitly, embedded within discourse aimed at making sense of phenomena that we observe. Ethnographies make use of implicit models when expository writing is used to convey to the reader the ethnographer's understanding of what constitutes the cultural and social milieu of those with whom the ethnographer has been engaged. A model, in this sense, is simply a way to relate how the parts of a whole relate to one another in forming the whole, hence any account of a system, even if expressed just using text, involves forming models. Within this broad characterization of model formation, we may distinguish formal from informal models through the former making explicit the parts being related using a formal language that includes symbols and rules for manipulation of symbols, thereby enabling consequences of the relations among the parts to be determined through reasoning expressed using formal language.

The language of mathematics has preeminently provided the formal language for deriving the consequences of the relations that have been identified, "[f]or mathematics is the science which draws necessary conclusions" (Peirce 1881: 97) since "[m]athematics is the study of what is true of hypothetical states of things" (Peirce 1902 [1956]: 1775). In contrast, the language of statistics has a different goal: "the aim of statistics is to provide good methods of collecting data to answer specific questions, and methods of drawing conclusions from those data" (Bailey 1998: 263).

These two languages – the language of mathematics and the language of statistics – interface with two kinds of formal models: theory models (M_T) and data models (M_D), respectively (Read 1990). The distinction between these two kinds of models is not absolute as the concepts used in the one may also be involved in the construction of the

other. What we select as an observation to be part of a data model is influenced by current theories we have about the structuring processes for the domain in question; what we posit as processes to be incorporated in a theory are influenced by observing patterning in phenomena making up the domain of interest.

The two kinds of models can be usefully distinguished through the way a model is validated. Data models are validated by their agreement with relevant observations from the domain in question and theory models are validated by their agreement with the relations expressed in a theory that purports to account for how it happens that the domain in question has the properties that have been identified in a data model.[1]

Evans-Pritchard's (1940) segmentary model for the Nuer is a prototypic example of the way a data model attempts to present patterning seen through observations. In his account, there is no theory in the sense of a hypothetical state of affairs whose necessary consequences have the segmentary model as an instantiation of those consequences. Rather, the validity of his argument depends on agreement with ethnographic observations and it is precisely here that critics of the segmentary model such as Kuper (1982) have challenged his segmentary lineage model: "I see no reason to salvage any part of the Nuer model … the Nuer model provides reliable guidance neither to Nuer social behavior nor to Nuer values" (p. 87, 88). If we accept Kuper's critique, then Evans-Pritchard formulated an invalid data model for the Nuer.

An example of a theory model can be seen in an argument by Johnson (1982) regarding conditions under which consensus decision-making may break down. The hypothetical state of affairs (to use Peirce's terminology) is the number of members, n, in a set, S, and the mathematically derived result is the number of distinct pairs, $n(n-1)/2$, that can be formed from the n set members.[2] Johnson forms an M_T by taking the set S to be a group of persons, pairs of members in the set to be dyads in the group, and then relates the number of possible dyads derived from the mathematical argument to the likelihood of consensus decision-making. For the later, he opines that for any activity dependent upon all of the dyads being activated so as to reach group consensus will run into one, or possibly both, of two limitations as the group size increases: (1) overload of the brain's short term memory capacity, which appears to be limited to about 7 distinct chunks of information being handled simultaneously or (2) the total amount of time required to activate and engage all of the dyads in consensus building discussions. The mathematical argument shows that the number of dyads will increase in proportion to the square of the number of persons in the group, hence the likelihood of failure to reach consensus increases rapidly with group size. Even with a group of size $n = 10$ there are already 45 possible dyads, suggesting that consensus decision-making may be difficult to achieve even in relatively small groups. Johnson used data given by Lee (1979) on frequency of conflict in two !Kung San groups (from which he constructs an M_D) as a test of the explanatory power of the M_T and finds consistency between the M_D and the M_T.[3]

3. Explanation Defined as Isomorphism Between Models

The two kinds of model come together, as shown in the above example, when we ask whether a given theory can serve as explanation for data observations. We can assert that a theory, T, is an explanation for data observations, D, when an M_T based on theory T is isomorphic with an M_D that incorporates patterning in the data observations, D. In some situations the data model may be implicit on the grounds that it is self-evident; but

in other cases, as the Nuer example demonstrates, forming a valid data model may be difficult. Explanation defined in this manner is, then, subject to the validity of the models M_T and M_D (Read 1990).

An explanatory argument satisfying the criterion of agreement between M_T and M_D need not be a valid explanatory argument since we may have a theory with a model M_T isomorphic to a data model, M_D, but where the isomorphism that gives the correspondence between M_T and M_D is based on invalid assumptions. For example, in a study of the behavior of fishermen in a small Jamaican fishing village, Davenport (1960) found almost perfect fit between an M_T game theory model in which a mapping from M_T to M_D was constructed by assuming that "nature" acts as one player and thereby, according to M_T, makes rational choices regarding which one of two strategies (the form of wave action, namely a rough or calm sea) to use against the other player, the fishermen, who had two strategies for fishing (fish close to shore or fish in deep water). The expected frequency distribution for strategy choices by each of the two players according to the M_T matched almost exactly an M_D for the actual strategy "choices" of the two players under this mapping. The argument is explanatory in form since M_T is isomorphic to M_D under the mapping of nature as one player and the fishermen as the other player, but is not a valid explanatory argument due to invalid assumptions used to construct the isomorphism. Obviously, in this context nature's action (current versus no current) is independent of the possible strategies used by the fishermen (Read and Read 1970).

Another way explanatory argument is not valid occurs when an incorrect theory predicts observations correctly (or at least within the bounds of measurement error), examples of which are legion. Yet another reason an explanatory argument may not be valid stems from an M_D constructed for simplified observations that obscure critical aspects of processes that structure data, as can occur with theory and models based on assuming the performance of a system expressed using properties averaged over the individuals in the system is no different from the behavior of the system expressed taking into account the properties of individual actions within the system.
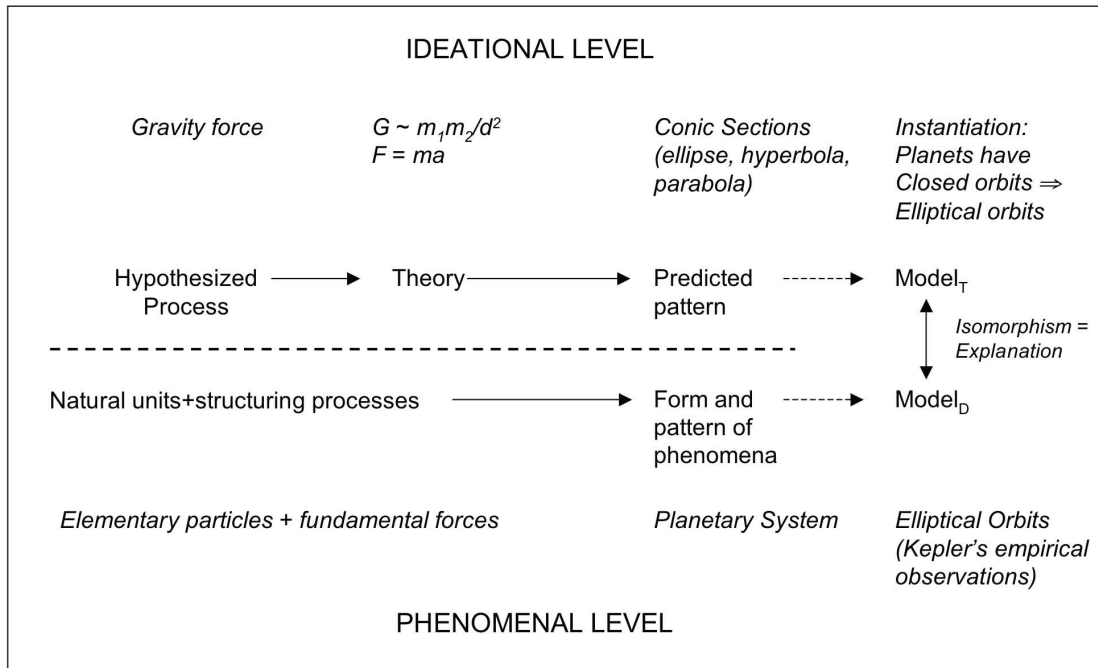
The criterion given here for an explanatory argument assumes both that an appropriate theory, T, for which an M_T will be constructed has already been identified and the data observations used to construct an M_D have already been determined. Both of these assumptions sidestep contentious issues relating to theory formation and data analysis that are far beyond the scope of this article. Rather than attempting to identify an appropriate theory (or theories) for the domain of interest, namely the behavioral, social and cultural properties of human societies considered in a holistic sense, we will consider instead changes in the underlying structure for theory formation and data representation that characterize the anthropological enterprise and how that contrasts with both the biological domain of reproducing organisms and the material domain of the physical universe. These three domains – cultural, biological and physical – differ substantively according to what constitutes units and what are some of the general processes that provide structure for the phenomena we observe, hence what constitutes the likely content of explanatory arguments.

4. Explanatory Arguments 1: Physical Universe

Consider first the physical universe. We can make a clear separation between the phenomenal domain of events in the physical universe and the ideational domain for theories about those events. As shown in Figure 1, the phenomenal level of the material universe is assumed to consist of natural units and structuring processes acting on those units, thereby leading to what we observe as the form and pattern of phenomena. We represent the form and pattern we perceive as an M_D. For example, we might take the natural units to be the elementary particles and the structuring forces the fundamental forces, or we consider higher level units such as planets that emerge from the structure generating processes acting on lower level units (lower part of Figure 1 in italics). The form and pattern of phenomena could relate to the planetary system where an M_D might be a description of the observed pattern of planetary motion; e.g., Kepler's three laws of planetary motion. The M_D need not invoke, and can be formed in ignorance of, the structuring processes – Kepler did not have a gravitational theory from which the regularities he observed in planetary motion were a consequence. The validity of his laws rested on their consistency with observations. The regularities were induced from detailed observations that made apparent patterning, which, in turn, could be expressed in a simplified form (e.g., elliptical orbits) that was faithful to his observations. Since an ellipse is characterized by two parameters (the lengths of the major and minor axes of the ellipse), his detailed observations could be reduced to estimates of those two parameters.

At the ideational level where theories are expressed as idea systems, we posit, in abstract form, the action of the structuring processes on the units (or possibly on higher level forms derived from lower level units), such as Newton's law, $F = ma$, linking force, mass and acceleration which can, in turn, be linked to his inverse square law for the gravitational force between two objects, $F \sim m_1 m_2 / d^2$ (upper part of Figure 1 in italics) via the common term, F. From this formal specification of the relevant structuring processes, we can derive, through mathematical reasoning, the logical consequence that the trajectory followed by two objects interacting with each other only through gravitational attraction will follow one of the three conic sections – ellipse, parabola or hyperbola. For planetary motion, we have instantiation of the theory as an M_T through the observation that planets follow closed orbits, hence the theory predicts an ellipse as an M_T for the orbit of a planet around the sun since an ellipse is the only conic section having the form of a closed orbit.

The isomorphism between the M_T constructed as a logical consequence of the theory based on the structuring processes hypothesized to determine planetary motion and the M_D formed from detailed observations on the actual motions of the planet establishes the theory as being explanatory of planetary motion described in the M_D. We may consider this argument as having the canonical form for explanatory arguments. For the physical universe we have a clear separation between the phenomenal domain to which the M_D refers and the ideational domain to which the M_T refers. As we will see below, this clear separation disappears when we consider explanatory arguments for human social and cultural systems.
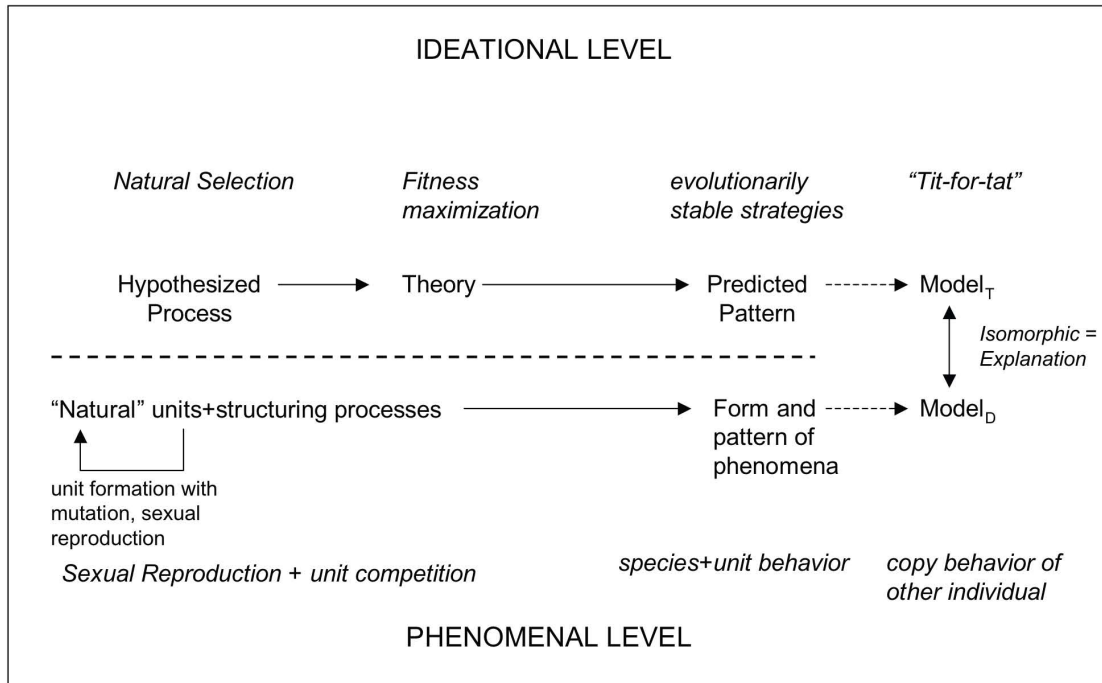
IDEATIONAL LEVEL

Gravity force $G \sim m_1 m_2 / d^2$ *Conic Sections*   *Instantiation:*
                         $F = ma$ *(ellipse, hyperbola,*   *Planets have*
                                                         parabola)   *Closed orbits* $\Rightarrow$
                                                                                   Elliptical orbits

Hypothesized ⟶ Theory ⟶ Predicted ┄┄▸ Model$_T$
Process   pattern
                                                          ↕ *Isomorphism =*
-    *Explanation*

Natural units+structuring processes ⟶ Form and ┄┄▸ Model$_D$
                                       pattern of
                                       phenomena

Elementary particles + fundamental forces   *Planetary System*   *Elliptical Orbits*
                                                                       (Kepler's empirical
                                                                       observations)

PHENOMENAL LEVEL

Figure 1: Physical domain with the canonical form of an explanatory argument. A data model, M_D, is used to represent the form and pattern of observed phenomena that in turn is the consequence of what constitutes the units of the system and its structuring process (text immediately below dashed line). A hypothesized process is formalized as a theory that implies a predicted pattern expressed in the form of a theory model, Model$_T$. An explanatory argument is based on an isomorphism between a Model$_T$ and a Model$_D$ (right side of figure). Illustrative examples for the terms immediately above and below the dashed line are shown in italics.

5. Explanatory Arguments 2: The Biological Universe

We can modify Figure 1 to take into account the biological domain of life forms (see Figure 2). With the origin of life, the role of units changed drastically from being, as it were, passive entities with fixed properties for which formation of units (primarily higher level units) occurred through processes not inherent in the units. Planets, for example, are higher-level units formed through physical processes, but those processes are not, themselves part of the properties of the higher-level unit. In contrast, we may view the origin of life as equivalent to the introduction of units capable of self-reproduction (with error); hence the process of unit formation became a property of the units being formed. The consequence of units being able to reproduce themselves with error leads to mutation in the kind of units that can be produced. This, in conjunction with a limited pool of lower level units that reproducing units use as part of the process of reproducing themselves, led to structuring processes that arise through competition among units over access to the lower level units necessary for the formation of higher level units through reproduction, hence to evolution. We refer to this structuring process as natural selection acting on individual (reproducing unit) fitness, with the latter measuring the relative rate of unit reproduction by one reproducing unit in comparison

with another reproducing unit in competition over other units also involved in unit reproduction. Evolution of life forms prior to the conditions under which species were able to arise was thus through a non-Darwinian mode of evolution characterized by information flow between units and dominated by horizontal (yet selective) gene transfer (Woese 2004).

IDEATIONAL LEVEL

Natural Selection   *Fitness*   *evolutionarily*   *"Tit-for-tat"*
                          maximization   *stable strategies*

Hypothesized ——→ Theory ————————→ Predicted ------→ Model$_T$
Process   Pattern

                                                          ↑↓   *Isomorphic =*
                                                               Explanation

"Natural" units+structuring processes ——————→ Form and ------→ Model$_D$
                                                  pattern of
unit formation with   phenomena
mutation, sexual
reproduction

Sexual Reproduction + unit competition   *species+unit behavior*   *copy behavior of*
                                                                          other individual

PHENOMENAL LEVEL

F**igure 2**: The biological domain is characterized by the addition of a process that enables a unit to form new units, thus a key aspect of biological units is embedding the unit formation process (reproduction) in the unit. Reproduction may have errors (mutations). A second, but not biologically universal, process is sexual reproduction, which made possible the formation of new units from information about unit formation embedded in more than one information donor unit. This led to partitioning of sexually reproducing organisms into species since an open-ended exchange system would allow for new units to be formed from information combinations that would have reduced viability and/or ability to reproduce. The introduction of processes not present in the physical domain (compare with Figure 1) ensures that biological explanatory arguments do not reduce to physical explanatory arguments. Illustrative examples for the terms immediately above and below the dashed line are shown in italics.

A second, major structuring process was introduced with sexual reproduction since that made possible intermixture of the (genetic) information necessary for unit construction from two (or possibly more) units. Yet an open-ended system of sexual reproduction could lead to the production of new units with reduced fitness in comparison to the donor units when the donor units have disparate genetic information and so the combination of genetic information from those two donor units might lead to

new unit forms with reduced ability to survive or reproduce. The biological solution to an open-ended sexual reproduction system was the partitioning of sexually reproducing organisms into bounded groups that we refer to as species with viable reproduction only occurring between members belonging to the same bounded group.

The consequences of these two new processes – unit formation based on the properties of units and partitioning of reproducing units into groups within which reproduction takes place – seem to be sufficient as a theoretical basis for what is referred to as Darwinian evolution. The implications of these two processes, either alone or in combination, for the characteristics of organisms provide a way to construct explanatory arguments regarding observations made at the phenomenal level of life forms. For example, recent work on allometric scaling laws in biology links organisms from the micro to the macro level as instances of the same metabolic process (West et al. 2002, Whitfield 2006). This leads to viewing life forms as having unity regarding the relevant structuring processes: "nature, via natural selection, has exploited a few very general physical, geometrical, and biological principles to produce the myriad diversity of life" (West et al. 2002: 2478).

The two processes central for the structuring of biological phenomena do not have counterparts in the physical universe (compare Figures 1 and 2). Consequently when we base explanatory arguments on these two processes we arrive at explanatory arguments that are logically irreducible to explanatory arguments based on just those processes said to characterize the physical universe; that is, explanatory arguments based on these two biological processes cannot be subsumed within the domain of explanatory arguments using just those processes that are part of the physical universe. The physical universe neither has a process equivalent to endogenously directed unit production nor to partitioning all units into groups of endogenously reproducing units.

6. Explanatory Arguments 3: The Social and Cultural Universe

A third, and major, change in structuring processes (see Figure 3) occurred with the evolution of *Homo sapiens* into a species having cognitive abilities that enable social organization to transcend patterns of behavior just arising from, and dependent upon, individual learning of appropriate social behavior through engaging in social interaction with other individuals in one's social group. With the development of language, social organization becomes entwined with shared conceptual systems that provide the context within which behavior occurs, thereby freeing social interaction from its previous dependency on face-to-face interaction as a way for the behavior of one unit to be "understandable" to another unit. The shift is from *interaction* to *social interaction* as defined by Parsons: "… in the case of interactions with social objects a further dimension is added. Part of ego's expectation … consists in the probable reaction of alter to ego's possible action, a reaction *which becomes anticipated in advance and thus to affect ego's* own choices" (Parsons 1964: 5, emphasis added; Read 2007a has developed a probability model for expressing the increased complexity in concept learning involved in the evolutionary shift from interaction to social interaction). While this shift may not be uniquely human, the means for so doing is elaborated through the shared conceptual system(s) that are part of what we refer to as culture; that is, individuals enculturated into the same cultural environment will share conceptual systems that make possible the kind

of social interaction identified by Parsons as fundamental to human societies (see discussion by Read et al. In Press).
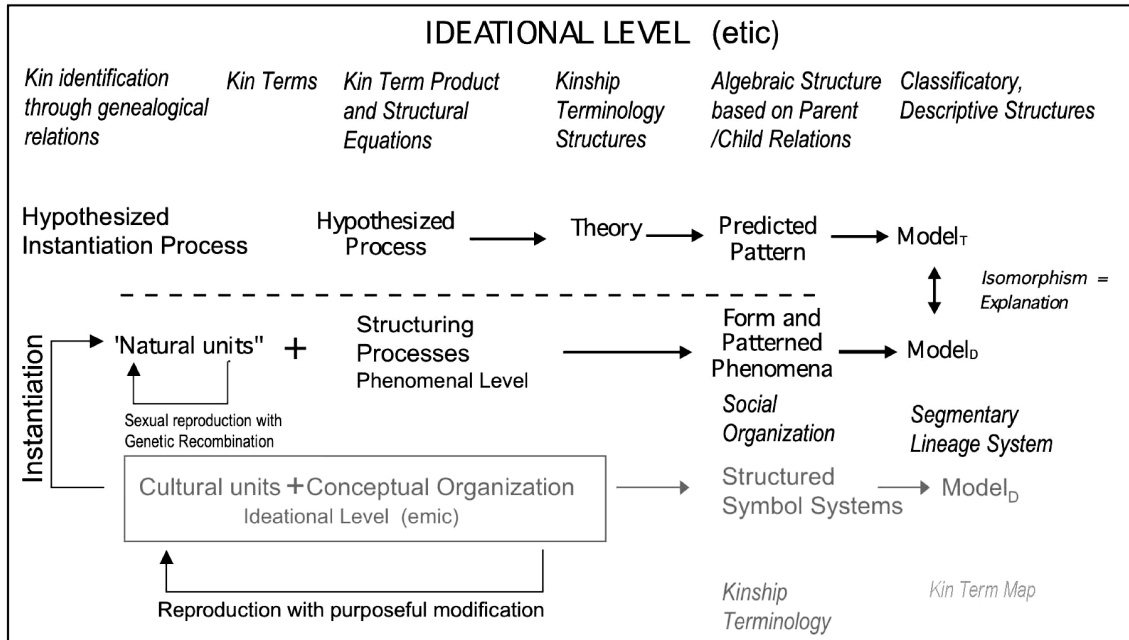
Figure 3: What is observed (below dashed line) includes culturally constructed idea systems that are part of the ideational domain of the observed. Observations now refer both to the form and patterning for the behavior of "natural units" = persons and to their underlying, cultural (i.e., shared) idea systems that are involved in framing behavior. The content for the cultural idea systems of the observed (labeled emic) is composed of cultural units organized into a conceptual system(s) (grey box). A conceptual system is reproduced through time, subject to purposeful modification because individuals have the cognitive capacity to evaluate and to (collectively) modify the system(s) into which they are enculturated. Two kinds of data models are relevant as indicated in black and in grey text below the dashed line: a data model for observed behaviors (first line of black text ending with Model$_D$) and a data model for a conceptual system (second line of grey text ending with Model$_D$). Cultural systems involve (abstract) ideas, hence there must be cultural instantiation to give cultural units specific content (vertical text) for cultural systems to frame behavior. At the ideational level of the observer (labeled etic), hypothesized processes include a process for cultural instantiation (line of text ending with Model$_T$) as well as a hypothesized process for the patterning observed in a cultural conceptual system (text in italics). Explanation is the same as in Figures 1 and 2, namely isomorphism between a Model$_T$ and a Model$_D$. Illustrative examples are shown in italics.

The explanatory framework is now much more complex because there is no longer clear separation between the ideational and the phenomenal domains. An

ideational domain is also embedded in the phenomenal domain of what we observe and represent through a data model. Separate from the explanatory arguments formulated by the observer, we also have the linguistically expressed idea systems of the observed. For example, when interacting socially we may bring to bear a culturally constructed and linguistically expressed kinship terminology system that defines for us those persons who we culturally consider to be our relatives. The terminology also identifies for us, as culture-bearers, patterns of behavior we should display to our cultural kin and, reciprocally, the behaviors we expect our cultural kin to display towards us (see Fortes's [1969:110] axiom of kinship amity; Palmer, Steadman and Coe 2006). The terminology system cannot be reduced to a system for codification of behaviors already in place (or to a system for carrying forward, into the future, behaviors from the past). Instead, it is a system of concepts and associated behaviors in which the system of concepts has its own logic that makes it possible to generate that system of concepts from a few core concepts and conceptual rules enabling these core concepts to be combined with one another to form other concepts, thereby forming what Fortes (1969:110) referred to as a "closed calculus" of kinship relations and Wallace (1970: 844) calls "the logical completeness" of a kinship terminology (see also Read 1984, 2001, In Press).

6.1 Cultural Idea Systems: Data Models and Theory Models

The kinship terminology is just one of the cultural idea systems that we obtain through enculturation as we mentally develop – from birth – through interacting with members of the cultural system into which we are being enculturated. The transmission of a cultural system through enculturation is analogous to the biological formation of new units through transmission of a genomic system (though the mode of transmission is not analogous [Read and Lane 2007; Lane et al. In Press]). Just as the genomic system is transmitted as a totality and not just as a set of traits, the cultural system is transmitted as a totality and not as a sum of traits (Read et al. In Press). As observers, we can formulate formal models of the cultural idea systems transmitted through enculturation, such as an algebraic model of the generative logic underlying the kinship terminology system we obtained as we developed into culture bearers through enculturation.

A kinship terminology system is part of our internalized, cultural repertoire and can be modeled as an M_D using the idea of a kin term map (Leaf 1971, 2006). The algebraic representation of the underlying generative logic for a kinship terminology system draws upon a theory that identifies the properties distinguishing kinship terminology systems from other cultural idea systems, along with the implications of those properties for generating the structure of a kinship terminological system. The algebraic representation is a theory model and so it is part of the ideational domain of the observer. The algebraic model becomes explanatory for the structure of a particular kinship terminology system when we establish an isomorphism between an M_T derived from a theory of kinship terminology structures and an M_D representing the structure of that kinship terminology. The latter is part of the ideational domain of the observed, yet is also included in the phenomena for which we construct explanatory arguments. These two ideational systems, the ideational system of theory-based explanatory arguments and the cultural, ideational system of the observed, will be distinguished here by the terms, *etic* and *emic*, respectively, though it should be noted that what these terms entail has been contentious (see Headland 1992 for a review of the issues).[4] I will use the terms

here in the following sense. By the *etic ideational domain* I refer to the concepts and ideas used to formulate theory-based explanatory arguments (see upper part of Figure 3, labeled etic) for patterning observed in the phenomenal domain, including the cultural idea systems of the observed. By the *emic ideational domain* I am referring to culturally formulated idea systems of the observed embedded within the domain of what is observed by the observer about the observed (see lower part of Figure 3, labeled emic). Emic cultural idea systems are validated through ethnographic observation and inquiry (Leaf In Press).

The emic ideational domain of cultural conceptual systems includes conceptual systems formed from cultural units (e.g., the kin terms in a kinship terminology [grey text, lower right side of Figure 3] or the concepts embedded within a structural opposition such as Enemy/Friend and given semantic meaning through that structural opposition [discussed in Read 2000]). A cultural conceptual system is both produced and reproduced through enculturation. Change in a cultural conceptual system can be purposefully and/or intentionally introduced by the "natural units" (= persons) who are the bearers of that cultural conceptual system. Whereas change in a biological system is extrinsic to the "natural units" (= biological organisms) since it arises through mutations occurring at a chemical level during DNA duplication, change in a conceptual system can be intrinsic to the "natural units" (= persons) through the cognitive ability of individuals to both monitor the translation of their cultural conceptual systems into behavior and to communicate and discuss what has been monitored, thereby enabling the coordination required to collectively modify those cultural idea systems.

6.2 Cultural Instantiation

The shared idea systems of culture-bearers are part of their ideational domain and so there must also be a way to link (abstract) ideas with the phenomenal domain of behavior in a mutually understood manner. In some cases, such as categorizations based on patterning and disjunctions observed in the material world, the linkage may be relatively straightforward (though how an idea system is organized as a system of knowledge may not be simple). Our cultural concepts of night and day, for example, relate directly to the astronomical fact of the earth rotating on its axis and we overtly and conceptually link the (imprecise) boundary between night and day to the common experience of observing the sun setting and the sun rising. What night and day may mean in a more cosmological sense for a particular culture, though, may be complex even though the link between these two cultural concepts and events in the material world is based on common experience. However, not all cultural idea systems are based this directly on commonly observed patterning in the material world. Concepts such as *human* versus *non-human* are not linguistic labeling of observable disjunctions in biological phenomena and instead are disjunctions culture-bearers have created and so culture-bearers must also construct the boundary (e.g., by linking the boundary for humanness to an action through which a "soul" or "spirit" is supposedly introduced into a developing, biological entity and thereby becomes human). Nonetheless, in either of these situations, abstract ideas must be projected onto the phenomenal domain to enable cultural idea systems to frame patterns of behavior. Read (2000, 2001, 2002, 2003) has called this projection *cultural instantiation* (see vertical text, left side of Figure 3).

Broadly speaking, cultural instantiation refers to the process(es) by which culture-bearers construct connections between their abstract, cultural idea systems and the phenomenal representations of those idea systems that provide the content for the culturally constructed frameworks within which behavior takes place and is culturally interpreted (see also Fischer 2008; Leaf In Press). For example, *bride* and *groom* are two (emic) concepts central to the American marriage ritual. But the concepts bride and groom do not entail which individuals are to be categorized as bride and groom in a particular enactment of the American marriage ritual. The latter depends upon a culturally agreed upon process by which the categorization takes place; that is, by cultural instantiation of the concepts, bride and groom in the form of a person recognized as the groom and a person recognized as the bride for the purposes of the marriage ritual. Though traditionally bride and groom have been equated with female and male sex, respectively, the sexual requirement for the cultural instantiation of bride and groom is currently under challenge by some groups in American society, but the concept of marriage with bride and groom is still maintained.

6.3 Formal Representation and Hypotheses of Cultural Instantiation

A data model can be at either the phenomenal level of observations regarding how behavior is structured (e.g., Evans-Pritchard's segmentary lineage system as a model for the behavior of individuals in a lineage form of social organization based on descent groups identified through tracing to an apical reference ancestor) or at the level of a conceptual system that is part of the cultural context for the individuals in the social system (e.g., organizing the kin terms in a kinship terminology into the form of a kin term map [Leaf 1971, 2006] based on kin term computations made by culture-bearers [Read 1984, 2001, In Press]). Formal representation of the process of cultural instantiation can be seen as a way to link these two kinds of data models.

At the (etic) ideational level of theory construction, we also need to include processes hypothesized for the way cultural instantiation gives content to the abstract ideas included in the cultural repertoire of culture-bearers. For example, we might hypothesize that cultural instantiation of abstract kin term concepts is sometimes based on concepts used in genealogical tracing such as genealogical mother or genealogical father (Read 2001). Other means by which kin terms are instantiated include adoption (which, for some groups, is indistinguishable from genealogical relations, as with the Inuit of Repulse Bay (Maxwell 1996), for example) and more culture-specific processes such as name-giving among the !Kung San, which provides the basis for their computation of kin relatedness through kin term products[5] (Marshall 1976; see Read 2007b for a formal analysis of the !Kung San kinship terminology).

6.4 Explanation and Emic Constructs

An example of constructing an explanatory argument relevant to an (emic) cultural construct is sketched (in italic text) at the top of Figure 3. Begin with a theory regarding the generation of kinship terminology structures (see Bennardo and Read 2005 for a detailed discussion of such a theory; see Read 2005 for a computer-based implementation, KAES, for constructing a $Model_T$ for a kinship terminology based on this theory). From this theory, deduce (mathematically) the structural form that will arise, given the initial conditions, which will then be a $Model_T$ for kinship terminology

structures satisfying those initial conditions. For example, the deduced terminology structure will have a core structure with the defining characteristic of a descriptive terminology (namely, kin terms used for relatives with a lineal genealogical relation to ego are not properly used for relatives with a collateral genealogical relation to ego) when the initial conditions for generating terms include only the specification that the generating terms are just a single Ancestor Term/Descendant Term reciprocal kin term pair (e.g., Parent/Child for the American kinship terminology). In contrast, when the initial conditions include both an Ancestor Term/Descendant Term reciprocal pair of terms and a Horizontal Term (e.g., a sibling kin term such as *ta'okete* ['older brother, sister'] in the Tongan terminology) as generating elements, a structure characteristic of a classificatory terminology (namely, kin terms used for relatives with a lineal genealogical relation to ego are properly used for relatives with a collateral genealogical relation to ego) will be the logical consequence (Bennardo and Read 2005, Read and Behrens 1990).

The argument becomes explanatory for the structure of a kinship terminology represented as a kin term map M_D when we compare the latter to an M_T (with initial conditions consistent with the structural properties expressed in the kin term map) and discover that the two models are isomorphic. For the American kinship terminology, as for all other terminologies analyzed to date, the M_D based on the kinship terminology and the M_T generated from the theory of kinship terminology structures are isomorphic, implying that the processes upon which the theory is based can account for the empirical observations.

7. Conclusions

As with the biological domain in comparison to the physical domain, explanatory arguments for cultural phenomena cannot be reduced to biological explanations because the processes identified in Figure 3 for cultural phenomena do not have a counterpart among the processes identified for biological phenomena in Figure 2. This implies that formal models relevant to cultural phenomena will not simply be models developed in other domains adapted to the particulars of the human social/cultural phenomena (Wimsatt and Griesemer 2007), but will be a combination of data models arising from detailed observations about cultural and social phenomena in human societies and theory models derived from theories based on processes hypothesized to structure the cultural domain of cultural units and their organization into conceptual systems (Read 2006, Lane et al. In Press). While there has been extensive work on identification of data models through intensive ethnographic observations, what constitutes the processes relevant to the structuring of cultural phenomena is far less developed. One of the primary roles of formal models in this area is to identify the necessary consequences (i.e., the mathematics) of hypothesized structuring processes through theory models that can be compared to data models for congruence with the structural forms identified in the two sets of models.

8. Supplementary Materials

Two supplementary files Kaes.jar (KAES - Kinship Algebra Expert System - Java Program - http://kaes.anthrosciences.net/) and KaesData.jar (KAES - Kinship Algebra Expert System - Data Files - http://kaes.anthrosciences.net/) are included as supplementary materials. These files should be downloaded to the same directory folder. Alternatively, the KAES application, along with examples of kin term maps, may be

downloaded from http://kaes.anthrosciences.net/, where there are two files to be downloaded with format corresponding to operating system. One file is for the KAES application and the other is for examples of kin term maps. The two files should be downloaded to the same directory folder and decompressed (e.g., unzipped for Windows users). The two decompressed files should be in the same directory folder. Run the Kaes.jar program and then select the kin term map from the initial window. A KAES window will open and the kin term map will be displayed. Actions that may be taken will be listed at the top of the KAES window.

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[1] The distinction between the two kinds of model, is not, as suggested by one reviewer, the same as between deduction and induction. Though data models derived using statistical methods may be inductive in form, deduction can also apply to data models as one can reason about empirical observations and a descriptive data model such as "all projectile points found at such and such a site are between 35 and 75 mm in length" is not based on induction.

[2] That the number of pairs is given by $n(n-1)/2$ in a set with n members can be shown using a proof by induction. **Theorem**: In a set with n members, there are exactly $n(n - 1)/2$ distinct ways for pairing the set members. Proof: (As is often the case, there are different ways a theorem can be proven to be true. I will present a proof by induction, rather than the more usual combinatoric proof, to illustrate the power of recursive arguments for constructing a mathematical proof. As a mathematician, I also consider the proof by induction to be aesthetically more pleasing.) (1) Show that the theorem is true for $n = 1$. If $n = 1$ there are 0 pairs and $1(1 - 1) = 0$. (2) Show that if the theorem is true for $n = k$ members then it must also be true for $n = k + 1$ members. Suppose the theorem is true for $n = k$ members. Consider what happens with $k + 1$ members. Select k of the $k + 1$ members. These k members may be paired in $k(k - 1)/2$ ways (because of the assumption that the theorem is true for $n = k$), and the remaining member may be paired to these k members in k ways. All together, there are $k(k - 1)/2 + k = (k + 1)k/2 = (k + 1)[(k + 1) -1]/2$ pairs. Hence the theorem is true for $n = k + 1$ whenever it is true for $n = k$. By induction, the theorem is true for all n. QED

[3] Read (1989) points out, however, that the M_D Johnson constructed is not a valid M_D for Lee's data.

[4] From *The Concise Oxford Dictionary of Archaeology of Prehistory:* "Emic. Pertaining to the view from within. Developed within the mind of an individual or a culture; meanings developed in terms of native categories." and "Etic. Pertaining to a view from the outside. In science this view might come from the observer: the analytic view, presumably replicable by any trained observer." The phrase, "developed in terms of native categories," provides a sufficient, but not a necessary condition for identifying what comes within the scope of the term, emic. The phrase "developed within the mind" implies that the scope of reference for the term emic is not limited to the species *Homo sapiens* (Douglas White, 2008 personnal communication). It should also be

noted that there is an inherent ambiguity in the etic/emic distinction in that through time ideas that were "etic" can be assimilated by culture-bearers and thereby become "emic" (Leaf In Press); for example, *sibling* with meaning brother or sister was introduced by Karl Pearson as a scientific term in 1903 (Oxford English Dictionary) but is now part of the repertoire of kin relations recognized by English speakers.

[5] The expression, relative product, has been used in the anthropological literature in an ambiguous, and not always consistent manner. In some cases the meaning appears to be a precursor to the formal definition of a kin term product developed by Dwight Read (1984). Read has defined a kin term product based on the way individuals compute kin relations with kin terms: "If alter X is my K (where K is a kin term) and alter Y is X's L (where L is a kin term), the product of K and L is the kin term M (if any) that I would (properly) use to refer to Y" (see Read 1984, 2001 for a complete, formal definition and discussion of a kin term product). For example, Anthony Wallace and John Atkins (1960) note that "there will be a set of terms, some of which may be 'lexemes' (but not primitives), which can be defined ... *as relative products of the primitive terms* of that lexicon" (1960:74, emphasis added). If, by "primitive terms" they meant, in the case of the American/English terminology, the kin terms mother and father and their reciprocal terms, son and daughter, then relative product is being used in the sense of kin term products. However, they go on to say that "the meaning of the term is given by a list of nonredundant English kin-types," which places the idea of a relative product back into the framework of kin-types (the genealogical relation between ego and another person) and kin-type products, rather than within the framework of kin terms and products of kin terms defined without reference to kin-types or products of kin-types. To add to the ambiguity, Wallace (1970) took a different tack and considered a relative product to be the same as the mathematical concept of the product of a (mathematical) relation defined over a universal set *U* of persons. Though the language of mathematical relations appears, at first glance, to capture the idea of one person having a kin relation to another person, the underlying problem with the mathematical formalism of relations lies in the requirement that "the definitions of kin terms do not become a function of the choice of the set *U*" (Read 1974:136), but any set, *U*, of actual persons is time-contingent whereas kin relations are, conceptually, time-independent. Another anthropologist, Robbins Burling (1970) suggested that the users of a terminology define kin terms through products of kin other kin terms: "It ought to be obvious to all that speakers can easily define some kinship terms by means of other terms. We can define grandfather as 'parent's father,' father as 'male parent,' parent as 'either father or mother,' and so forth. Our ability to give verbal definitions surely reflects our understanding of our kinship system, but this ability has been only very imperfectly reflected in the analyses of anthropologists" (1970:16). Burling's rationale for his suggestion is an earlier parallel to Read's (1984) motivation for his formal definition of a kin term product through the usage of kin terms and both contrast with the formalism of kin-type products as it was used in componential analysis, according to Wallace (1970), to express kin term definitions as class-products. Regardless of ambiguity in what is meant by a relative product, it is evident that anthropologists in the 1960's and 1970's were grappling with the idea that kin relations may be computed with kin terms. Rather than use the expression, relative product, with its ambiguity as to whether it is referring to products defined through products of kin-types or products of kin terms, I will use the expression *kin term product* with its formal definition based on the way users of a terminology calculate kin relations directly with products of kin terms.