Introduction.

Popper and Eccles (1977) debated the three-world problem that has confronted anthropology in terms of:

- World 1: The physical world (and human brain and behavior in that world)
- World 2: Mental activity and human consciousness.
- World 3: Objective culture, "which is the creation of World 2 but takes on its own distinct and permanent existence."

The topics of this article and those of Read (2008) on formal empirical models confront the question of how these three worlds are related. How is it possible for Objective culture to take on a distinct and permanent existence? My Figure 1 brackets the three-world problem at two levels: that of the sciences (networks, cognition, culture) and how these play out at the individual level of brain, mind, and behavior or organism-environment linkage. Arguments between scientists such as neurophysiologist Damasio (2007) and philosophers like Gluck (2007), seemingly irreconcilable, fail to resolve these problems. For anthropology the interfaces between brain as a physical organ and the mind as a nonmaterial dynamical organized response pattern mediating the organism-environment (and self and other) interface creates problems of apparently incommensurate duality.

Yet, the sciences today are undergoing major transformations and re-synthesis. They in turn are affected by transformations in physics, biology and ecological psychology in dealing with complex systems and, in particular, the dynamics of complex systems. I want to address here how these new syntheses affect anthropology and those social sciences concerned with human cognition, culture, and networks. Cognitive anthropology (CA) is caught in a position of having to reconcile, somehow, individual cognition in the human brain with the existence of cultural patterns in terms of shared and meaningful symbols. I will not debate here the merits of CA as practiced in the 1960s and the solutions wrought by assuming that human thought operates through self-evident categories ("components" of meaning), and that symbols are somehow
reducible to componential analysis, context, opposition, indexicality\(^1\), and deixis.\(^2\) Expressed in language, the convergence from raw sounds (phones) to phonemes emerges by memory and social convention (Skyrms 1996). Somehow, by analogy to phonemes, it was alleged that morphemes and word meanings in contrast sets emerge through components of meaning.

Because animals were recognized in laboratory experiments as making categorical judgments about colors, shapes, emotions, and the like, both material and “immaterial,” 1960s CA assumed that categories and their components must somehow impart meaning to the human mind. For humans, however, the assumption that mind operates through categories fails because humans also think relationally, as has been demonstrated experimentally (Hummel and Holyoak 2005, Penn, Holyoak, and Povinelli 2008). Thus, the first problem with CA in the 1960s, as shown in the first upper circle of Figure 1, was that meaning was seen as defined by categories, without consideration of relational cognition.

For Popper and Eccles, there is a fundamental problem in the relation of World 1 and World 2. How is mind (something immaterial) related to matter, i.e., to brain and the physics of behavior? Following the pioneers of cybernetics in the 1930s and the emergence of increasingly sophisticated electronic computers in the 40s and 50s, and given that the brain is chemo-electrical, and on the analogy of contrast sets in linguistics, the second problem of CA in the 1960s was the assumption that the brain operated as a digital computer, a belief exaggerated by Lévi-Strauss in his 4-volume attribution of binary elementary logics to slow-moving “cold cultures” portrayed in *Mythologiques* as trying through repetition of mythic themes to resolve irresolvable contradictions. Oddly, this belief coincides with the Newtonian view of natural forces operating in four coordinates of space and time, as if time were ticking along and needing to be calculated digitally, in the brain, instead of analogically as flow. Einstein’s conception of light as constant flow that distorts gravity as velocity expands to light speed has impacted the social sciences only very slightly. Much contested, for example, but validated experimentally (Michaels and Carollo 1981) are Gibson’s (1950, 1955, 1966, 1972, 1979) findings on direct perception.

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\(^1\) Indexicality is a word or expression whose reference may vary from speaker to speaker: some indexicals are “I,” “this,” “now,” and “here.”
\(^2\) Deixis is reference by means of an expression whose interpretation is relative to the (usually) extralinguistic context of the utterance, such as: who is speaking; the time or place of speaking; the gestures of the speaker, or the current location in the discourse.
Thought (individual) Relations (social)

Cognition       Networks
1960s: Categorical  Perceptual flows
But also:   of relations
Relational    Behavior as epi-
Mind         sodic relations
Brain         Culture
Perception        Emergent from
Emotion         social interaction
Gibsonian        in structurally
Behavior       cohesive sets
–Environment

Fig. 1: The three-world problem at two levels: Individual and Social, Thought and Relations
(Arrows represent a connective and circular logic, but influences are omnidirectional). Cognition and Culture are purposely not placed on the same plane to avoid the suggestion of reification of culture on a superorganic level of “group thought.” Culture, rather, is an emergent and not always singular or consistent distillation of practices in a cohesively organized group to which cognition may be directed, so there is a reflexive level of cognition in thinking about culture.

Summarizing experimental work in the Gibsonian tradition, Michaels and Carollo 1981:11-13) note that perception is "an ongoing activity of knowing the environment" that is not sliced problematically into past/present/future or into Newtonian time slices but a continuity of related parts of events, where "nowness" may or may not appear as a relevant phenomenal experience and is not axiomatic to a theory of knowing. It is relevant information that specifies the event and its parts, each of which last over time. A "whole event is perceived ... by a continuity of those 'parts'" and bounded by change to and from other perceived events, events in space-time and not metric coordinates. Information is not partitioned, it is coextensive with the event.

The experimentally validated solution to the mind-body conundrum, then, is that the embedded organism and its environment constitute a single system (Gibson 1986, West and King 1987, Swensen and Turvey 1991, Oyama 2000, Wagman and Miller 2003, Turvey 1991, 2009, Turvey and Shaw 1979, 1996). Events are bounded in perception by change in action that have networks of connected parts within events and recurrence across events. These views accord with
Hutchins’ (1991, 1995) on the use of material anchors in studies of human cognition, i.e., the human-cognitive environment connection.

Time-series of events thus lend themselves (not emically but perceptually) to network coding and analysis. Such studies may be done at many different time scales. In our studies of kinship networks (see White and Johansen 2005 for an ethnographic example) there are intergenerational events such as marriage, childbirth, death, migration, and proximal interactions within these and other event boundaries and more micro or macro time-scales of event sequences. The network links among events and actors exhibit structural and dynamical patterns, including recurrences for which tools exist for studying complex dynamics (see Carollo and Moreno 2005 for methods), fractalities (White and Johansen 2005:136-137), and structural cohesion as a predictive network variable in relation to cultural formation.

**Cohesive groups in networks.** Cohesive blocks are found operationally in a manner that fits the basic conceptual form for the idea of the cohesion of groups, the way cohesion is perceived for groups, and the way that cohesion ties a group together both internally and by resistance to being dismembered. It also shows the way that networks provide a particular set of the degrees of freedom in how cohesive groups may relate to one another through overlap (e.g., membership in multiple communities) and through core-periphery subgroup hierarchies for levels of cohesion. This opens the way to the following hypothesis:

**The Cohesion and Consensus Hypothesis:** Levels and variations of cohesion within social networks for society as a whole and within its varying segments, which can be measured for level-specific cohesive blocks within networks, will tend to predict levels and variations in cultural consensus, provided that the connections that define the network have some positive perceptual relation to the subject(s) of cultural consensus.

A simple example was provided in the formulation of the measure of network cohesion by White and Harary (2001): they predicted how a Karate Club studied for two years by Zachary (1977) divided its membership between the club owner and the instructor, and the order of secession of those that followed the teacher to a new club. This has a cognitive dimension because (1) individuals must assess their relation to the owner and instructor in relation to others and decide with whom to affiliate or disconnect, and (2) they also assess who are their closer friends or allies in the network and who are more distant and how the two alternative leaders stand in relation to their closer friends. Personal attributes of the two leaders could not have
made a better prediction. Defectors moving to the teachers side by breaking with those on the owner’s side do not follow an individual decision rule but follow a rule for the group: the tie that is least cohesive with the owner’s side is broken first, and in case of a tie for cohesion, the tie broken is more distant from the owner.

Moody and White (2003) showed (1) strong effects of levels of cohesion of individual students in their friendship blocks on their reports of attachment to high school and (2) how the cohesive strengths of co-memberships in the cohesive blocks of business alliances align with similarities in the choices of firms in their political party alliances of firms in party politics. In both cases, none of the other network or attribute variables outperformed the predictiveness of the cohesion measure.

Powell, White, Koput and Owen-Smith (2005), using the Moody-White measurement of structural cohesion, analyzed time-lagged effects from year to year of multiple variables in the choice of partners for strategic collaborations in the biotech industry and found they were strongly predicted by level of cohesion in the cohesive blocks to which potential partners belonged the year before. None of the other network or attribute variables outperformed the cohesion and diversity measures.

Multiconnectivity that implies structurally cohesive circuitry, especially for networks of organizations, is like a series of stacking blocks as shown in Fig. 2 (the children’s stacking-blocks game: with each successively smaller block stacked on a peg representing successively more k-cohesive groups), the top block representing the most cohesive subgraph of nodes in a network. The oddity is that blocks on different stacks may be part of a shared platform for their upper blocks (representing overlap for their lower blocks). The later Fig. 3 will show how individual blocs are defined by internal level of network-tie cohesiveness.

![Fig. 2: Stacking blocks, analogous to 3 cohesive hierarchies with overlaps of nodes in common](Google image search “stacking blocks” p. 2)

This kind of structure is difficult to envision because each $k$-component contains all blocks above a certain level and overlaps apply downwards to the blocks below. It is best stated
abstractly as a mathematical definition for precisely bounded maximal subgraphs of a larger graph whose subgroups for levels $k$ are found by algorithm, which give results easily perceived by humans when viewed in a suitable format. That is, such blocks are detectable in a sparse graph by keen visual perception after the nodes are pulled together if they are connected and pushed apart according to the length of the singular chains that connect them but which are not embedded in cohesive blocks. This is known as the spring embedding or FDP (Force-Directed Placement) visualization algorithm. A single longer chain both “connects” and “pushes apart” two nodes relative to nodes that are cohesively connected.

Differences between “integrated” single cohesive blocks and multiple “segregated” or “overlapping” cohesive blocks are illustrated in Fig. 3 (a)/(b) with two slightly different model networks: in one the ties are fully randomized (and thus are likely to be integrated), while in the other some strategic ties are added to create segregated (but in this case overlapping) organization clusters. Fig. 2 shows two graphs with 20 nodes, one with 38 random edges and another with 33 random edges plus 3 that force more cohesive complexity onto the graph. Fully random edges typically create embedded levels of “socially integrated” $k$-cohesion like a nest of Russian dolls. Fig. 3 (a) shows a sparse random graph with 20 nodes and 40 links, each link adding one degree to each of the two nodes linked, so the average degree per node is 4 edges (some have more than four and some less). Those that have degree four or more do are circled but no set of the 14 nodes with degree 4 forms a 4-component. There are 17 nodes, however, that form a 3-component. When edges are completely random, as in 3 (a), cohesive components form a single hierarchy, as in the case of the biotech network discussed above, where the graph is also cohesively integrated. In Fig. 3 (a) the 3-component is a subgraph of the 2-component, which nests in the largest (1-) component of all nodes that are connected.

The colors of nodes in Fig. 3 illustrate $k$-cores, which are uniquely defined in any network for the integers $k=1,2,3,...$ where some of the higher $k$-cores may be empty. A $k$-core (for $k=1,2,3,...$) is the largest subgraph in which each node has degree $k$ or more. Every $k$-component is a $k$-core but not every $k$-core is a $k$-component. In graph 3 (b) the two are equivalent for $k=3,2,1$, which is usual for perfectly random graphs and for “integrated” graphs with no tendency to form separate or overlapping $k$-components. The $k$-cores of a graph are easily computed, e.g., by Pajek, by iteratively deleting all nodes with less than degree $k$ and recomputing degree, retaining those with $k$ or more links. Like the measure of subgraph density, the use of $k$-cores
(defined by Foster and Seidman, 1989, Seidman and Foster 1978) is often taken in network analysis as a measure of group cohesion, even though this usage is patently invalid (White and Harary 2001). For a more sophisticated use of $k$-cores as fingerprints of network structure, recognizing that cores may be disconnected, see Alvarez-Hamelin et al. 2006). A subgraph of two cliques (completely connected) may have 50% density and yet be disconnected, so that density is no measure of subgraph cohesion. Similarly, a $k$-core for any value of $k$ with more than $2k$ nodes may be completely disconnected.

Fig. 3 (b) shows a spring-embedded graph created the same way but with 3 edges added to show the difference between a $k$-core and a $k$-component. Here the red nodes form a 3-core but there are two overlapping 3-components within the 3-core, and the share node 3. The Moody and White (2003) algorithm here is replicated in R by McMahan (2007) for easier computation.

![Fig. 3](image)

Fig. 3. Cohesive blocking in graphs with 20 nodes and different numbers of random edges. Colors of $k$-cores are $k=3$ in red, $k=2$ in greens, and $k=1$ in yellow. This differs from sorting by degree, as shown by circled nodes in 3 (a) for nodes with degree $\geq4$. (a) has a single cohesive hierarchy, (b) has two $k$-components that are not differentiated by the $k$-core concept as they belong to the same 3-core.

It is easy to see that all the red nodes in the graphs 3 (a) and (b) have 3 or more edges with the other red nodes, hence they are 3-components, but also that there are two separate (segregated but overlapping) tricomponents in Fig. 3 (b). For small sparse random graphs, the combination of spring-embedding and $k$-core coloring usually allows visual identification of $k$-
components, just as people with mature skills in relational cognition are able to perceive $k$-components in their friendship groups intuitively.

**Fig. 4** shows the results of the cohesive blocking applied to Fig. 3 (b) using the algorithm of Moody and White 2003 (as implemented by McMahan 2007). Nodes in both 3-components (3-connected) are red, but the splitting diagram to the right shows that there are two 3-connected components. The output vector computed by the McMahan (2007) algorithm (Appendix 1) tells which nodes are in each of the 3-components, as shown by dotted ovals in 3 (b):

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[[3]] [1] "v2" "v3" "v4" "v7" "v15" "v16" "v19"
[[4]] [1] "v3" "v5" "v8" "v12"
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Note that “v3” occurs in both 3-components in the separate but overlapping dashed ovals.

Armed with this way of measuring the *distribution of cohesive groups at different levels of cohesion*, it is easy to see how a Cohesion and Consensus Hypothesis could be tested by direct correlation with a pairwise cultural consensus matrix (Romney, Weller, and Batchelder 1986). In a perfect match a network of type (A: integrated cohesive groups) would match a single-consensus model, and one of type (B: overlapping or separate cohesive groups) would match a divergent-consensus model. Areas in the graph of higher and lower correlation between consensus and cohesion could be mapped and compared.

**Test of the Cohesion and Consensus: P-graphs and Structural Cohesion**

San Juan Sur (SJS) is a peasant community in the Turialba Canton of Costa Rica studied by Loomis and Powell (1949) in contrast to a nearby hacienda community (Atirro). Costa Rica was then seen as the most democratic country in Latin America, “the land of peasant proprietors,”
where many of the rising hacendado class arose from peasant communities. The focus of their study was the transition to more stratified society, occurring as

“peasant holdings are being gradually throttled by the large fincas and corporations thus reducing the status of the people from that of peasantry to peonage. Increasingly larger numbers of people are becoming “journaleros” and working for a subsistence wage as peons of the large land owners. What, then, might be expected if the country continues in the present trend toward a peon-patron type of system. For example, is there really a larger lower class on the hacienda than in the peasant community? How do the classes in these two situations compare with those in society at large? Especially important is the influence this transmutation may have upon the possible acceptance of communism by the rural people who have been and are being forced to accept the status of peonage.”

(1949: 448) ³

One focus of this study was on the impact of formal and informal social systems – social networks – on social change. Loomis investigated visiting relations between peasant proprietor families living in the San Juan Sur (SJS) neighborhood and on the nearby hacienda of Atirro. The network data on visiting ties that they collected form a simple directed graph: each arc represents "frequent visits" from one family to another. “The exact number of visits was not recorded. Line values classify the visiting relation as ordinary (value one), visits among kin (value two), and visits among ritual kin [value three], i.e., between god-parent and god-child.”

What light does the Loomis network study shine on issues of networks, cognition, and culture? Two of my hypotheses above can be tested with the structural cohesion measure applied to these data. First, the SJS peasant community is described ethnographically as egalitarian, and members were asked to rate one another on a scale of social class rank from 1-10, as were the residents of Atirro. This allows a comparison of structural cohesion with consensual social class ratings in the two communities and a positive test of the hypothesis. SJS judges rated 59% as “middle class” and 18% as “lower middle class” (p. 156) Nine of the ten judges in SJS rated themselves identically to how others rated them (p.149), and a SJS leader rated himself one rank lower than others rated him. In Atirro similar agreement was the case for eight of ten judges while the community was equally split on ratings of one resident and for a leader three judges agreed with his rating while six judged him higher. SJS has the type of loose-community integration structure that should be associated with a single-core cohesive hierarchy, as per the

³ Note this concern at the very start of the Cold War, preceding the Cuban revolution (1962), the subsequent revolutionary movements in Nicaragua and El Salvador, the covert Contra wars, and the U.S. installation of CIA backed dictator, drug king Manuel Noriega (never officially President), in Costa Rica in 1983.
cohesion-consensus hypothesis. “In Atirro, … the two upper classes are removed in orientation from the other people in the village, and their associations are directed largely outside the community. The top prestige leaders… were not chosen from these two upper groups and there exists a barrier of significant proportional between the two lower groups and the two upper groups.” “The lack of informal communication between [the lower group] leaders and the finca and commissary directors in the classes above is noteworthy” (p. 157).

Second, SJS and Atirro differ organizationally. The sixty Atirro residents interviewed were employees of a finca who worked for a small daily wage, lived in a tightly nucleated cluster, were much more mobile than the SJS residents (sixteen had lived there for less than a year) but enjoyed a rent-free “casa” during their employment. An administrator directs the work of the finca and a “mandador” directs the workers and is answerable to the finca owner. Here, structural cohesion would be expected to be fragmented but with some fragments indicating organizational specialization, as for example, in the finca hierarchy.

Fig. 5 shows the SJS network, with three types of directed ties differentiated by color: red for kinship, blue for ritual kinship, and black for other. Edges without arrows are symmetric ties, arcs with arrows are asymmetric. Most of the blue nodes are within the large structurally integrated 3-component of the network, where the nodes are colored red, and in which most of the ties are red, kinship ties, some are those of ritual kinship and a few are other. The green nodes are in the 2-component, and the single blue node connected only in the 1-component. The cohesive algorithm and spring embedding are the same as in Figs. 3 and 4.
**Fig. 5.** SJS network, with directed ties colored red for kinship, blue for ritual kinship, and black for other. Edges without arrows are symmetric, arcs asymmetric. Most of the blue nodes are within the large structurally integrated 3-component of the network, where the nodes are colored red, and in which most of the ties are red, kinship ties, some are those of ritual kinship and a few are other. The green nodes are in the 2-component, and the single blue node connected only in the 1-component.

The correlation between structural cohesion and consensus is strong and positive in SJS, not only in a general sense, but in positively inflected correlation for SJS between k-cohesion and higher class level, and between k-cohesion and leadership status. Further, if the network of visiting among kin is examined, and the symmetric ties are removed, there are 46 remaining asymmetric visiting ties, and these ties form a connected but partially ordered visiting hierarchy which is extremely unlikely to occur by chance \((p=3 \times 10^{-14})\), and which indicates a systemic direction to directed visits. Since several families direct their ties to single targets, the pattern of asymmetric visiting among kin is from siblings with families to their common parents. In some cases this is evident over three generations. So there is also an “extended family structure” in SJS with a common – that is, consensual – pattern in visiting behavior.

Loomis and Powell (1949) conclude their article, in light of their concern with community disaffection and the spread of communism, with “The middle class philosophy of thrift, hard work, and higher regard for property is not as prevalent in the hacienda community as in the peasant proprietor community” (p. 157). In Atirro, there is little cohesion overall, there are few kinship or ritual ties, what little cohesion there is is fractured. The largest set of extended family visiting ties are hierarchical and connected to the hacienda employment hierarchy, and there are no correlations between cohesion and other judgment variables like perceived leadership or class level.

**Perception and Action.** Case study findings on school friendship networks (Moody and White 2003) and of business alliances in relation to political affiliation (same authors), and biotech collaborations (Powell et al. 2005) all imply an ability to act upon perceptions of cohesive network structure without any linguistic labeling of the cohesive groups or levels of cohesion, and that these perceptions are largely correct. The first example is a small network in a single organization, while second and third are medium and large sized networks of firms and other alliances of the firms (to parties, to other organizations that serve functions for the human biotech firms). While there are no names for \(k\)-components in social discourse, the ability of a
child to order the stacking blocks is the prototype for the cognitive ability to recognize cohesive stacking in friendship groups intuitively, as orderings of this sort are intrinsic to social cohesion.

**The thought and language fallacy.** The dominant anthropological view of the early 1960s was that thought (and culture) was conveyed through language, which we sometimes hear today in a quote from Helen Keller: "Before I had words I had only sensations." Keller, however, was deafblind. It has been shown experimentally that with sight alone humans have enormous complexity in their understanding of social relations. Orangutans and other higher primates also have understanding of complex relations acquired by watching and listening. What this means for our Figure 1, if you want to pencil in more content, is that you can add notes about where words and language fit in Fig. 1 as opposed to nonlinguistic cognition. We can, for example, make up stories about culture as taking on “its own distinct and permanent existence,” and such stories are supported experientially by the duration of groups with a high degree of structural cohesion (Moody and White 2003) and more specifically, where social networks form detectable communities (Estrada and Hatano 2008). The algorithmic science of finding the unique “strongest boundaries” of network communities, which may also overlap into hybrid communities, is barely in its infancy. Every population in which there are data on the kinds of elements and relations that are thought to constitute a culture or subculture can presently be tested against the Estrada community detection algorithm. White and Harary (2005) show that it is exactly the elements in the Estrada model that, with time-series network data, predict the exact process of dissolution of ties in the ethnographic study of a small group by Zachary (1997) that split in two as a result of conflict between leaders.

We know from experimental comparisons of human and other animals that relational reasoning (Hummel and Holyoak 2005) is critical to humans’ ability to negotiate their extensive skills in social networks. The special relation between human cognition and social networks includes those of “non-perceptual relational similarity based on logical, functional, and/or structural similarities between relations and systematic correspondences between the abstract roles that elements play in those relations” (Penn, Holyoak, and Povinelli 2008:111). This would explain anthropological research findings that I discuss below in examples of how social behavior in many societies is organized around relational patterns present in the *structure and dynamics* of network relations that are not coded as social categories in the language of those interacting. In the 1960s, however, evidence was ignored from nonverbal tests of modes of
reasoning (Cohen 1969, Cohen et al. 1968) that showed relational rather than analytical categories.

**Case studies, principles, measurement, and hypothesis testing.** Case studies and theoretical as well as measurement principles are presented here in two preliminary and one concluding wave: first, empirical problems and their implications for theory, reinforcing positive tests of the behavioral network-cognitive consensus hypothesis; second, the development of a synthesis that incorporates the various levels of the physical and social sciences. Third, principles of continuity and discontinuity in culture, sharing and diversity and stability, metastability and instability in complex systems, and problems of theory and method are left for the concluding remarks.

Wave one gives five kinds examples of problems that stand in the way of an integration of network approaches with the study of cognition and culture: (1) understanding complexity in relational systems; (2) understanding the role of relational perception in addition to categorical thinking as a basis for culture; (3) understanding unnamed relational categories; (4) understanding that the perception of network roles within a community and from the outside is not a matter of imposing multiple metaphors helter-skelter but in finding relational similarities such as those that might plausibly underlie the perception of social or economic roles (White and Reitz 1983, Smith and White 1988, Reichardt and White 2007); (5) understanding how culture and agency are formed, at a level above that of individuals as agents, through the vehicle of research on cohesive and central subgroups in networks (Moody and White 2003; Estrada and Rodriguez 2009).

Wave two poses the various conundrums of privileging methods of science or methods of hermeneutics, and the defects of dualisms and forms of positivism, in working towards an integrated social science and the possibility of some convergence on approaches to complexity in various branches of study: physical, biological, and sociocultural.

Wave three shows how the reopening of the problems of continuity and discontinuity in culture, sharing and diversity and stability, metastability and instability in complex systems (including culture) can help in the new synthesis. It concludes with problems of theory and method and why competition occurs between dualist and monist social theories as described by Leaf (1979).

**EXAMPLES OF THE PROBLEMS OF SYNTHESIS.**
The foundational complexity problem for relational systems. Relational structures do not always reduce to categorical ones, which would destroy my argument. Boyd (1969) attempted to prove that relational structures in social networks may align with the componential definitions of the words that partition social roles into sets, at least under certain restricted cases such as the “classificatory” logics of section systems in Australia. To understand the true complexity of section systems, however, start with four suits: spades, clubs, hearts and diamonds. Let them define the fundamental units of a relational system. Each person is assigned a single fixed suit. Members assigned black suits (spades, clubs) must marry one suit of opposite color (e.g., spades to hearts, clubs to diamonds), and their children are assigned to a single suit (e.g. clubs) who must marry an opposite color (e.g. clubs to diamonds). The color rules are the same for males and female.

It follows that, in any descent line, for either the male or female descent lines suits and colors will vary in alternate generations, resulting in precisely two types of patrilines and matrilines between which all marriages occur. The relational structure of this sort of system is isomorphic with a binary categorical system in which lineages are uniquely categorized as to which other lineages they marry. This is true for both patrilineages and matrilineages. What is not determined is the specific marriage structure, that is, what is the distribution of actual marriages in terms of how they satisfy the section requirements. The section system has implicit matrimoieties, implicit patrimoieties and implicit alternate generations moieties but that is all. The section system has an arbitrary distribution of marriages so long as section rules are satisfied, which is the case when one can marry in the same or in alternating generations (+2, -2) of the correct moieties. Appendix 2 shows how, beyond the structure of moieties, Boyd failed to prove the equivalence between the componential definitions used to define kinship terms in section systems and some arbitrary number of lineage-based subsets.

Relational perception and the categorical fallacy. The Goodenough-Fischer debate is famous in anthropology for demonstrating that the classificatory categories thought to be fundamental to ethnology (“comparative ethnography”) lack validity because not even two ethnographers working in the same culture in the same place and time will draw the same conclusion. Goodenough (1956) and Fischer (1958) failed to agree, even after much discussion in print, on to how to classify people’s residential choices from data in the censuses of the Trukese (Chuukese) Atoll in Micronesia. Skyhorse (1998, 2003), however, given the kinship
genealogy collected by Goodenough and Fischer, constructed the community network of kin ties and found that the solution to describing the residence pattern was to code network relationships husband’s and wife’s matrilineage. With nearly 100% uniformity, couples went to live with the holder of lineage land depending on who was closer: the landholder of the wife’s lineage or that of the husband. This corresponds to the view of David Schneider, a member of the ethnographic team but not a participant in the debate, that people “belonged” to the land “closest” to them in the network. This was not a “classificatory” solution, imposed by the ethnographer, but a “relational” one evident in the residents’ network behavior. For each marriage, competing access to land, matrilineally inherited, draws in one of the two spouses and their family, those who are most able, through network proximity, to benefit from the rights of the titleholder. In this example, it is the proximity and network cohesiveness, closeness and mutual attraction with titleholders, that structures residential choice. Principles of usufruct, land-title privilege in allocation of land use, and sensible residence choices also tend to optimize the longer-term equality of land distribution.

**Kin Networks and Kin Terms.** Kinship networks are related in the first place to a cultural logic of kin terms, described in Read’s (2008)’s computational cultural models of relative products (e.g., Br of Fa = Uncle) as the basis of kin term systems. His studies show that networks of terms are generated logically. My next example on Pul Eliyan kinship, using data from Leach (1961), shows that these relative product kin terms are not simply related to behavior through instantiation (applying the terms to people, for example), but enacted within a network that takes on entity and constituent entities that emerge in their own right through network dynamics. These two levels -- instantiation and enactment -- are closely related. On the one hand there is conceptual embedding in a logic of relations; on the other a network embedding generated by behavior. Read (2008) observes that in kin-term systems that take the brother/sister relation as a primitive generator of the kin-term logic, (a) elder/younger sibling terms are found only for same-sex and never for brother and sister, (b) brother/sister is invariably observed to be a privileged relation, (c) the kin-term system (e.g., of the Dravidian or Australian type) entails a marriage rule, and (d) these “systems” are demonstrably of the classificatory type. When we look at the kinship networks of societies defined by the implied and observed endogamous relations within such classificatory systems (in which the inclusiveness of endogamy may include outsiders marrying in or insiders migrating out), not only is the “marriage rule” (e.g., “sections”)
instantiated by individuals virtually without error, but emergent “global units” are instantiated with some allowance for exceptions at the fringes of these units (Houseman and White 1998a,b, Denham and White 2005).

In non-classificatory kin-term systems, members of a kinship community in which blood marriages are prohibited typically have some community-based social and resources advantages relative to those who marry out if they are structurally endogamous (White 2009) and this is often indicative to a system of correlated social and economic classes (Brudner and White 1997). In the alternate case where blood marriages are preferred, societies with within-lineage marriage rights tend to allow competitively achieved inequality within and between lineages with distributed strong ties of reciprocity through broad inter-lineage and inter-clan alliances, a highly stable system (White 2009, White and Houseman 2002). As an hypothesis for cases where blood marriages are preferred but lineages are exogamous, as extrapolated from Lehman (1970) and Bell (2008), marriage alliances tend to be asymmetric, with wife-takers over wife-givers, or vice versa, and patterns of alliance tend to be unstable without an ideology of circular connubium.

Read’s (2009) explanation of how agreements (taking variants into account) collect around a formal computational model is by willingness to recognize oneself in the other and the other in oneself: kin terms “model” reciprocity and identification of roles that could be taken. There are new kinds of work here that can be done on cultural models, and it should or could logically be done best by new studies, easily implemented (White and Jorion 1992), on the relations between structural cohesion and consensus, and between reciprocities and role identifications and manifest behaviors.

Sidedness and the naming fallacy (Example: Pul Eliya). The shift in views of human cognition from categorical to relational is congruent with the human ability to cognize the complex role and structural patterns of social networks, independent of language. This is where Houseman and White’s (1998a,b) findings about kinship networks differ from Read’s view of kinship as organized by kinship terminology. These two views are congruent, but in the following way. Read views kin terms as organized by relative products of kin terms, and in classificatory systems (which spring from taking siblings as a kin term generator, like parental and child terms and their products, along with gender, relative age and spouse terms) they entail marriage rules. In general, however, Read views the application of kin terms to genealogical and other relations as “instantiations.” Having studied kinship networks qua locally defined
genealogical links, we find that there are an abundance of clear-cut network patterns, like the balance principle of signed graphs (Cartwright and Harary 1956), which are recognized by members of a community in their behavior, but which are not necessarily coded by linguistically marked categories, such as named moieties or named descent groups. A reading of the *Pul Eliya* restudy by Houseman and White (1998a) of Leach’s ethnographic network material will make this clear.

A network analysis of marriages based on Leach’s (1961) complete genealogy of the Sri Lankan community of Pul Eliya can be done by simply treating parents (e.g., marriages or single parents) as nodes and defining two types of links: those to a male’s parents and those to a female’s parents (White and Jorion 1992). Dual organization of the marriage networks is indicated by the fact that among kin linked by common ancestors, 100% of the male links and the nodes they connect can be divided into two sides (White 1999) such that women (daughters) from one side marry men on the opposite side (and similarly for mothers and their parents’ nodes). Names for matrimonial moiety organization (the two sides), however, are absent. Egocentric kinship terminology, however, is consistent with sided marriage. The computational question here is: How can egocentric kin terms serve to organize coherent sidedness in a community that is structurally endogamous given that people commonly do marry blood relatives? The computational answer is simple: If we regard the male links as in-group (+) ties and female links as out-group (-) ties, the dual balance theorem of graphs (Cartwright and Harary 1956) applies so that if all blood marriages are composed of cycles that link husband and wife to a common ancestor by an even number of (-) ties, the blood-ties network will be sided. Hence, the “practice” of sided marriage in a kinship network of this sort is sufficient to result in a sided “structure” of the network, without recourse to naming of sides as social groups, or as defined by unilinear descent. Pul Eliyans also lack a rule for membership in corporate male descent groups which would be consistent with network male-based (viri-)sidedness. For sidedness to work, individuals have to recognize which relatives are marriageably “sided” and which not. In theory, this should apply as well to affinal networks such as chains of siblings and siblings-in-law. Sidedness in these chains, however, is not fully encoded by kinship terminology in Pul Eliya, so by these criteria, some individuals would be free to marry in ways that are not properly sided. There is a minority of wrong-sided marriages, and the name for them is *dos*, for “improper” marriages. Pul Eliyans do have a concept for network sidedness, then, that is not rooted in
kinship terminology. They also have a reason not to practice strict viri-sidedness because irrigation rights and extended family residences in compounds are normally inherited by sons but allocated to a daughter when she lacks brothers. To inherit and avoid dos marriage, the heiress will marry a man from a distant village whose sidedness can be ignored (e.g., two brothers from a distant village can marry women on opposite sides of Pul Eliya). Thus, community members have an elaborate understanding of network sidedness irrespective of kin terms and manage to retain consistent sidedness among the majority of the village that are biconnected through common ancestors in spite of a minority of sided marriages. What this exemplifies is that Pul Eliyans have a relational calculus for sidedness within the links of the network itself that is independent of the kin-term calculus, i.e., a pre- or extra-linguistic cognition of network structure used to apply the term dos, a practice of non-dos proper marriages, and strategic marriages to preserve cognatic inheritance relations without violating the integrity of a cognized but not fully linguistically inscribed network sidedness.

**Network roles and the fallacy of conceptual blending.** Fauconnier and Turner (1998, 2002) argue that cognitive integration is a matter of “conceptual blending,” the use of bundled concepts of how one set of related elements are overlaid over one another through analogy or metaphor to create a new conceptual map. Again, this is a matter of perceiving relational parallels. Network analysis provides block models of how bundles of related elements are related through common network structures, either individually or when the structures themselves are overlaid (White and Reitz 1983, Smith and White 1988, Reichardt and White 2007), in what is known as relational(-structure) equivalence. It is not that “blending” can be done arbitrarily, but that the alignment of structures into congruent mappings is something that humans can perceive conceptually and that adds new meaning to such constructions. Much of innovation consists of exaptive learning, that is, of envisioning a new function or network overlay to an existing concatenation of elements and their relationships (Lane et al., 2009, esp. Chapters 1-3)

**New Developments in SNA: Cohesive blocks, subgroup centrality, communicative communities, and the methodological individualist fallacy.** Network analysts also have their individual or methodological biases, and one of them, oddly enough, is the bias toward defining network centrality in terms of individuals rather than groups. Freeman (1979), for example, defines three intuitive concepts of centrality, each relating to the centrality of individuals: number of links (degree), overall closeness to others, and relative betweenness on the shortest
paths between others. Estrada and Hatano (2008), in contrast, define a measure of subgroup centrality that characterizes the relative participation of each individual node in all subgraphs in a network. This measure, over a large sample of empirical networks, is almost totally uncorrelated with betweenness centrality for individual nodes. Estrada and Rodriguez (2009) go a step further to exploit their group-oriented method to define uniquely-determined network communities based on patterns of shared subgroup centrality and the clustering of “communicability” in networks. It is these measures that should predict degree of cultural sharing among members of a network, no matter how extended.

**CONCLUSION: PROBLEMS OF A NEW SYNTHESIS.**

The integration of network approaches into cognitive anthropology reopens problems of sharing and diversity; continuity and discontinuity in culture; and stability, metastability and instability in complex systems (including culture). New approaches can help in new syntheses at the ethnographic level and theoretical level, including comparison and explanation.

**Diversity and Sharing.** The concepts of structural cohesion around which communication, social reinforcement and agreement may shape cultural consensus. These group-oriented network measures also identify social boundaries that may overlap and that may change rapidly. Members of a cohesive group may also affiliate elsewhere to create complex network formations.

**Continuity.** Many anthropologists have felt obliged to explain how continuity in culture occurs. Sir Herbert Spencer coined the term “superorganic”, as if society was an organism whose existence required shared culture. This pseudo-explanatory word-game was continued by Durkheim who referred to collective consciousness. Alfred Kroeber and Leslie White continued the use of the superorganism concept as if it were an explanation. We see the term “distributed cognition” in use today in cognitive anthropology. J. W. Powell in 1880 coined the term “enculturalation” to describe what we see today in evolutionary synthesizes of developmental (ontogenetic) processes. For Oyama (2000:71) and many contemporary researchers: “What passes from one generation to the next is an entire developmental system” that is inheritance-dependent but as the outcome of a dynamical process, a view that can benefit from further empirical research testing the modern synthesis in developmental and cognitive psychology supported by new experimental evidence of direct perception (Michaels and Carollo 1981:11-13), with network embedding as an unexpected solution to the mind-body two world problem.
**Discontinuity.** Dynamical processes, like episodic direct perception, have discontinuities, often cycling among different states. Leach’s (1961) study of the Pul Eliya emphasizes that there is no corporate charter of norms linked to the permanency of descent groups that continue indefinitely, and all is not harmony: reversing the dynamic of Chuukese residence, alienation of property from the agnatic compound creates opportunities for others to strategize the capture of land claims, while the rights of daughters allow bequests that alienate property, and many of the conflicts in the village revolve around contested claims. Statistical changes as well as institutional ones (like policies introduced by British colonial authorities) may change frequencies of behavior that change the context in which new expectations and norms are formed around changed network formations of structurally cohesive groups.

**Metastability and instability in complex systems** (including culture). White and Johansen (2006) provide a longitudinal network study that documents the ethnogenesis, growth, and decline of ten lineages linked through marriage (structural endogamy) in a nomad clan. It focuses first on how the formation of structurally endogamous group through strategic intermarriage provides the cohesion for a leader of a long-range migration to form a new clan and move to occupy new territory, then on how equalitarian rotating leadership creates a period of reciprocal inter-lineage alliances that holds the growing population together for many generations. Intense competition for resources favor large sibling sets with many siblings-in-law while population pressure shunts less competitive smaller families off to resettle in towns and cities. The growing numbers of interlinked nomads and ex-nomads eventually support the movement of wealthier lineage leaders and their families to the city, and ties among the lineages gradually thin out to the point where the clan ceases to be cohesive, as new occupational forms are taken up.

**Conclusion.** The kinds of problems that in the past half-century hindered anthropology in its aspiration to the status of science in addition to its natural history and humanistic foci are these:

Under structuralism, modeling became either an impossibly complex or a subjectively arbitrary exercise, often impossible to falsify.

In the scientific camp, modeling became too positivistic in focusing in methods over theory, i.e., instead of empirical study of the relation between theory models, empirical models, and inferential statistical problems of fit between competing models and alternate theories.
In the humanistic camp, the banishment of the logics of premises and derived conclusions in which Popperian falsification of conclusions casts doubt on one or more premises has led to arbitrarily constructed complexities which are thus in principle unfalsifiable.

Within cultural anthropology, which tends to be an American designation, both camps tend to commit the fallacy of prioritizing words over deeds when it is both that should be considered.

The existence of these problems of theory and method tend to guarantee that, at least within American anthropology, there will be the competition between dualisms and monism described by Leaf (1979). The synthesis of cognition and network embedding offers an enriches both fields and broadens the conception of anthropology.
References.


Appendix 1: Activating the cohesive.blocks algorithm to produce Fig. 2. Paste into R for execution. The data for the figure are on-line and copy/paste are all that’s needed.

#GNU cohesive.blocks() (c) Written by Peter McMahan 2007 posted in October.
require(igraph)
require(digest)
require(RSQLite)
source("http://www.charting1968.net/CohesiveBlocks.R")
g <- read.graph(file="http://intersci.ss.uci.edu/wiki/Vlado/random20nodes36edges.net", format="pajek")
gBlocks <- cohesive.blocks(g,verbose=TRUE,cutsetHeuristic=TRUE)
V(gBlocks)$label <- V(gBlocks)$id
max.cohesion(gBlocks)
lapply(gBlocks$blocks,function(i){V(gBlocks)[i]$id})
#plot.bgraph(gBlocks,layout=layout.spring,vertex.size=14)
plot.bgraph(gBlocks,layout=layout.kamada.kawai,vertex.size=14)
write.pajek.bgraph(gBlocks,file="gBlocks")
Output:
[1] 2 3 3 3 2 3 3 3 2 2 3 2 3 3 3 2 1 3 2
[[1]] [1] "v1" "v2" "v3" "v4" "v5" "v6" "v7" "v8" "v9" "v10" "v11" "v12" 
"v13" "v14" "v15" "v16" "v17" "v18" "v19" "v20"
[[2]] [1] "v1" "v2" "v3" "v4" "v5" "v6" "v7" "v8" "v9" "v10" "v11" "v12" 
"v13" "v14" "v15" "v16" "v17" "v19" "v20"
[[3]] [1] "v2" "v3" "v4" "v7" "v15" "v16" "v19"
[[4]] [1] "v3" "v5" "v8" "v12"

Appendix 2. Boyd (1969) “attempted … to relate the theory of [permutation] group structure to the concepts of kinship grammar and componential analysis,” at least for the classificatory
section systems of Australia. A section system, as André Weil (1949) noted, can be described as a mathematical group structure in which any of the two of the opposing pairs (A, B) in one of the three moieties of a section system form a permutation group \( M_i \) consisting of all the permutations of a set, e.g. \{A, B\} and \{B, A\}, a permutation function \( f(M_i) \) for pairs \( i \) in (A, B) – here, \( f(M_1) = \{B, A\} = M_2 \) and \( f(M_2) = M_1 \), an identity \( I = f(f(M_i)) = M_i \), and an inverse \( f^{-1}(M_i) \) where in general \( I = f^{-1}f = ff^{-1} \) but where in the specific case of \( G = 2 \) elements \( f = f^{-1} \).

Permutation groups, of course, may have \( n > 2 \) elements, in which case \( f = f^{-k} \).

Boyd’s theorem (p. 248) was that for binary relations, defining a network among persons in a set \( E \), if the network is strongly connected, every edge in \( E \times E \) is either positive or negative, \( \phi(E) \) is a function that maps elements (people) in \( E \) into \( n \) classes (e.g., two, in the case of moieties) and the sign of the edges in the relations on sets \( E \times E \) is preserved in homomorphic bijections between \( \phi(E \times E) \) and \( \phi(E) \times \phi(E) \), then (1969:148) the following are equivalent: (1) every closed walk is positive (2) pluses and minuses multiply as usual; and the society can be partitioned into two non-empty subset such that negative relations hold only between persons of different subsets, and positive relations hold only between persons of the same subset (3) any two walks between points \( x \) and \( y \) have the same sign.

In Boyd’s mind this theorem generalized for any \( |G| = n \), that is, for any number of subsets of nodes in a section system, hence could describe the kinship roles in a kinship network with a section system, and hence these roles would correspond to the ways in which a componential analysis of kinship terminology would correspond to kinship roles. Unfortunately, he was mistaken. Boyd (1972:339) notes that François Lorrain pointed out that the theorem on p. 145 (Group Partition) on which his main theorem (p. 148) was based had an error, but in spite of that error “the theorem on p. 148 is correct because the false theorem holds in the special case where \( G \) has only two elements.” This statement is not accurate because no such restriction is placed on the main theorem (p. 148). In short, Boyd shows only an instance of the balance theorem for moieties, where \( |G| = 2 \), which was already proven by Cartwright and Harary (1956). The only difference, if any, is that moieties provide names for the two sets of nodes that are bipartitioned in a strongly connected balanced graph.