Developing Theory of Network Structure/Dynamics and Ethnographic Applications

Introduction

The past 35 years have seen a massive development of tools for network analysis, starting with Clyde Mitchell, Harrison White, and INSNA social scientists,[1] and burgeoning applications to ever-wider sets of problems in the social sciences. Not seen has been the development of an integrated theory of networks that situates explanatory principles in a common conceptual framework. That is the goal of the present work,[2] along with application to the explanatory frameworks used in a series of long-term field sites (in which the PI, graph theory consultant Harary, and our collaborators, including students in training, are engaged in study).

Unlike sociology, which defined and forged ahead with social networks as a theoretical paradigm (Mullins 1975, Berkowitz 1982, Burt 1982) on a par with "heavy-duty approaches such as structure-functionalism, Marxism, and ethnomethodology" (Wellman 2000:4), cognitive anthropologists[3] narrowed their focus on networks to egocentric cognitive constructions that come to have shared components, while cultural anthropologists generally looked askance at formal methods. Even within INSNA, in spite of "explosive growth of interest, …membership hasn't commensurably grown in size": Despite "ready availability and easy use of heavy-duty methods… and ...the participation of so many smart people, our work has not cumulated enough or developed enough integrated theory. Why is it that many people with network analytic sensibilities do not participate? When I ask, they tell me that our methods are too hard and our scope is too narrow. Or else, they think that only a metaphoric 'network' sensibility is enough. I wonder how to reach out to them so that a broad, rigorous structural analytic perspective flourishes" (Wellman 2000:7).

Concepts A: Cohesive Blocking (A New Methodology)

A new methodology for analyzing cohesive and adhesive blocks in networks that is crucial to theorizing about clusters of meaningfully related elements such as people in social groups, items in a material culture, or concepts in a symbolic world was developed under the previous NSF award, and published in a prominent methodology journal (White and Harary 2001). A k-cohesive (or k-adhesive) block in a graph of relationships is a maximal set of nodes in which no pair can be disconnected by removal of fewer than k nodes (or edges, respectively, for edge versus node connectivity). A k-cohesive block is also a maximal set of nodes where every pair has k or more paths that are node-independent (with no intermediate nodes in common). White and Newman (2001) give a fast algorithm to compute all such paths for large networks. Nine previous NSF project-related publications [1-3,6,7,11,13-15] show the

---

[1] Members of INSNA, the International Network of Social Network Analysis, have been the primary producers of new methodology.

[2] In doing so, it may be possible as well to bring network theory back into anthropology, where it died once those experimenting with the approach turned from problems of fluid social structure to the study of transactions, ritual enactment, symbolic action, and contemporary themes of cultural anthropology

[3] E.g., students and colleagues of Romney; these were not the only anthropologists to study networks, but network anthropologists were few and far between (Schweizer, White, Bernard, Whitten and Wolfe among them), although Hage worked with graph theorist Harary to develop a more general structural approach parftly encompassed here, but with new structural twists and an emphasis on network dynamics.

predictive consequences of these measures of cohesion or adhesion for substantive variables in ethnographic and sociological studies.

The proposed next stage of the research develops and applies this mathematical modeling framework as part of a general theoretical integration of network approaches as applied to a wide range of subjects in anthropology and ethnohistory. For example, the network structure used by White and Harary to illustrate the methodology can be summarized in a new way (for easier integration with other approaches) using a concept lattice (Ganter and Wille 1999): Figure 1 show all cohesive and adhesive blocks in a network of friendships (see inset) among karate club members (Zachary 1975a,b). The nodes in this lattice represent sets of individuals and their memberships in inclusive hierarchies of groups defined by cohesive and adhesive blocks in the network, some of which overlap – as indicated by the lowermost node of the lattice, in which the downward intersections are those among groups. Size of nodes in the lattice reflects the size of each group, and upward arrows show inclusions of smaller groups in larger ones. To visualize the groups in this figure, take any node on the diagram and draw an oval that includes the node and all those linked to it by downward lines (inversely to arrows). Each of nine such groups includes the bottom node, representing the karate club teacher. Each group is labeled with a number that gives its node or edge connectivity, followed by A for an adhesive block or C for a cohesive block (in parentheses are the sizes of groups). There are four concentrically tighter adhesive blocks (1-2-3-4 in the A series), but two divergent hierarchies of cohesive blocks, each several layers deep (1C-2C-3C-4C and 1C-2C'-3C' in the two series). In this case 1A=1C(=1C') includes the entire group, which can be disconnected by removal of the teacher (hence its status as 1C for 1-cohesive) or by removal of the link between T and 12 (hence 1A for 1-adhesive).

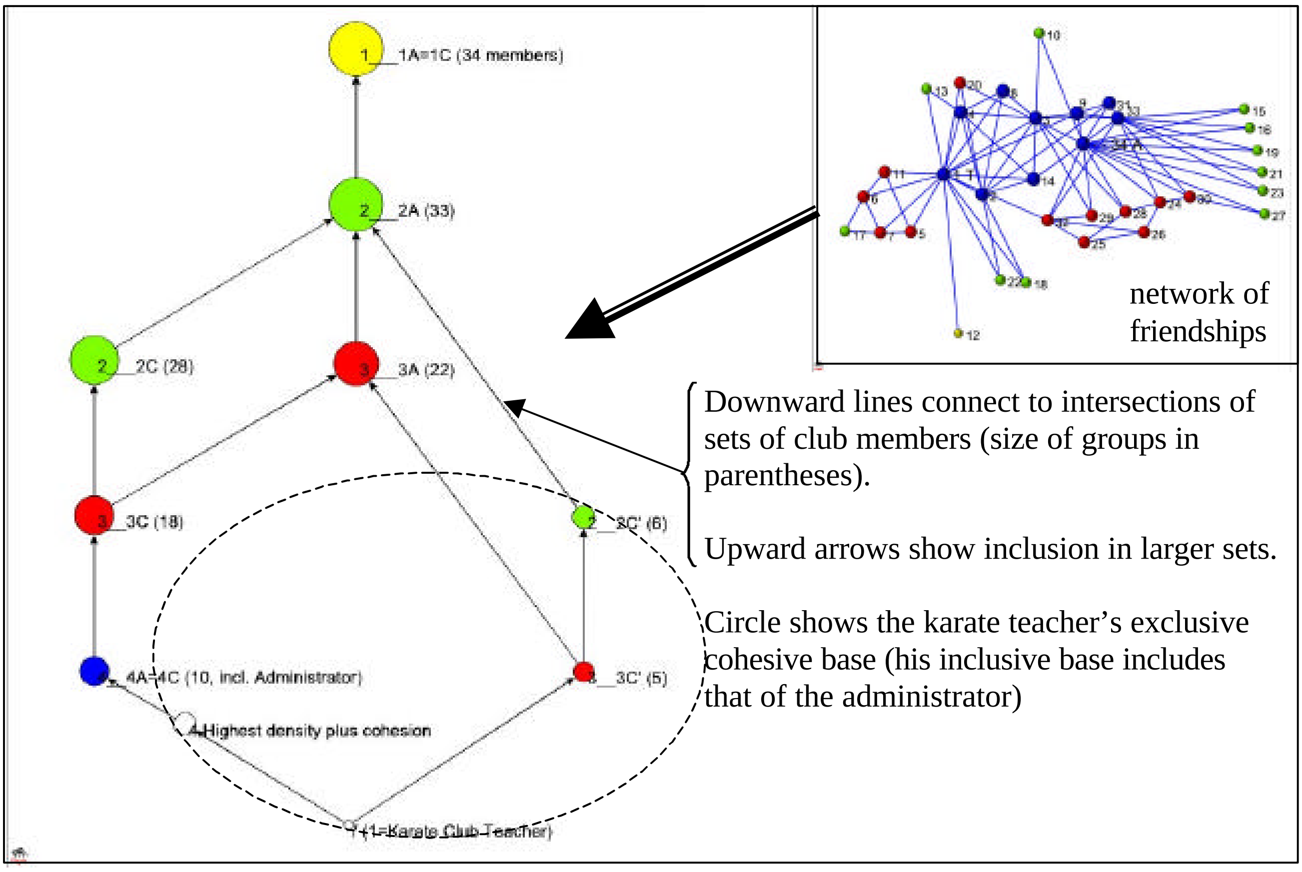


Figure 1: The concept lattice of cohesive and adhesive blocks of a network of friendships (inset) among karate club members

The structure seen in Figure 1 is a concise display of the sociologically meaningful groups on the basis of their network ties.[4] By definition, a k-cohesive block is contained in a k-adhesive one,[5] and the hierarchies of blocks are severely constrained by the fact that any two with connectivity k will have no more than k-1 nodes in common. Hence we can read from the figure that while 2C and 2C' intersect by downward lines at the lowermost node, their intersection can contain only a single node (the karate teacher). We can easily grasp from a correct reading that the teacher is the only person who is a member of all the groups and that his social support exceeds that of administrator, who belongs to 7 blocks but not to the densest 4-block within 4C nor to 3C'- 4C' (these are indexical of the teacher's autonomy).[6] This might help to explain why the teacher is the one who initiates a conflict with the administrator over his salary. White and Harary also show how the group structure displayed in the figure (and in finer detail) predicts the lines of cleavage by which the club fragments into two parts. The dynamics of dropping ties when members are forced to choose between leaders also play a role in prediction. This interplay between structural moments and dynamic effects of social interaction in predicting outcomes constitutes one of the main foci of this research.

Cohesive structures may apply not just to social networks but to all kinds of networks (symbolic, material, multipartite), and we will experiment in the next research period with other types of networks using ethnographic materials from our case studies. What is exciting here is that the hierarchical nature of cohesion (with limited overlaps) is ideal to represent emergent properties of systems that are quasi-classificatory, with 'exemplars' of hierarchical elaborations of associated concepts, but that also contain 'anomalies' as crosscuts across categories. This takes us back to the debates of ethnoscience of the 60s and 70s but in an entirely new way, one that is open to new discoveries of emergent properties.

Concepts B: Formal Patterns in Networks

As shown in Table 1, while in cohesive blocking connections are grouped *within* sets, graph coloring is a homomorphism (generating color equivalence as a partition of nodes; edges can also be partitioned ed by similar principles) that goes in the opposite direction to observe the organization of equivalence sets when connections are limited to those *between* sets. Homomorphisms such as colorings are complementary to lattice structures (such as cohesive blocking hierarchies, which do not result in partitions) as principles in graph theory. Like colorings (and unlike cohesive blocks), blockmodeling is a homomorphism that generates a partition of nodes into nonoverlapping sets, but without the constraints of graph colorings (which cannot put two connected nodes in the same equivalence set). Sociological blockmodeling (Lorrain and White 1970, White, Boorman and Breiger 1975) is to the concept of <u>role</u> (analogous or similar position emerging out of a system of relations) what

---

[4] Concept lattices can also show clique structure (Freeman 1996) but cliques can only intersect, which makes it difficult to identify more inclusive groupings. The same is true for overlaps of group membership (Freeman and White 1993), which also fail to capture cohesiveness in large networks. The latter has been shown to have sociologically important predictive consequences for social classes, business alliances, ethnicity and political organization (Moody and White 2000, White and Harary 2001).

[5] White and Harary explain how this is consistent with Menger's Theorem that k or more node-independent paths between two nodes implies they cannot be disconnected by removal of fewer than k nodes, and node removal removes edges while edge removal does not remove nodes.

[6] These include students at a site not supervised by the administrator.

cohesive and adhesive blocking are to that of group.[7] In the next phase of research we will generalize cohesive blocking to the study of role structure as developed by Oeser and Harary (1962, 1964, 1967),[8] where we try to find tasks that cohere with one another, people who cohere with tasks, and coherence among formal roles (algebraic products of people by positions and positions by tasks) as opposed to emergent ones (people by people and people by tasks). Table 1 shows some of the ways in which these approaches differ. No one as yet has shown how these different aspects of network modeling, mathematically well formulated, might be unified around an integrated sociocultural theory of the socially interactive basis of cognition (see Hutchins 1996) and the coherence of human behavioral systems (see Moore 1998; Goodenough Ch. 11 1964). At the mathematical level, our research steps will be to establish a common formal language for comparison and integration of these four approaches, then to formally restate each model in the common language of graph theory, and finally to work on the formal conditional relationships amongst them (as we have done with connectivity and conditional density in developing the methodology of cohesive blocking. The next stages, discussed below, are to develop a substantive theoretical framework of hypotheses that allow us to measure and integrate the formal aspects or dimensions of these models in relation to empirically testable applications. Our guiding construct is to use a heuristic concept of "structural coherence" that seeks to express how these different formal aspects of the mathematical structure of sociocultural phenomena are embedded in real-world material, spatiotemporal and cognitive processes.

	Cohesive Blocks	**Graph Homom.**	**Blockmodel (Informal Roles)**	**Role Structure (Formal Roles)**
Coherence	Group Blocking	Exchange Opposition	Analogous Positions	Allocational Positions
Relations	Multiple	Single	Multiple	Tripartite*
Within Set	Connectivity	Disconnection	Similarity	HxH social PxP formal TxT task seq.
Between	Inclusion	Connection	Similarity	Bipartite maps
Structure	Hierarchy	Partition	Partition	H/T=H/P x P/T
Equivalence	(None:overlap)	Coloring	Regular	Multiple
Overlap	Minimum	None	None	
Reflexivity	n.a.	Disallowed	Allowed	

*Humans, Positions and Tasks (Oeser and Harary 1962, 1964, 1966; Biddle 1979a,b)

Table 1: Formal Patterns in Networks (as elements in the study of coherence)

Concepts C: Coherence among Formal Patterns

One of the goals of the present research is to develop a process model of relational coherence: how do elements assort and then cohere and synchronize in a (complex) social system? Our guiding hypothesis is that the engines of structural coherence (heuristically defined above) are coupling processes generated by the synchronization and necessary bundling of tasks and activities – both behaviorally and cognitively – within a field of social action. A related goal is to articulate this theory in terms of networked processes and

[7] The concept of regular equivalence (network homomorphism) as developed by White and Reitz (1983, Reitz and White 1989) is an explicit formulation of blockmodeling that fits ethnographic applications, by finding more general positional analogies outside the context of small group studies.

[8] There is also a Petri Net approach of Lupu and Sloman (1995) that can be assimilated to this framework.

emergent structures. Some of the insights of complexity theory are easily articulated within this framework and generate the following kinds of hypotheses:

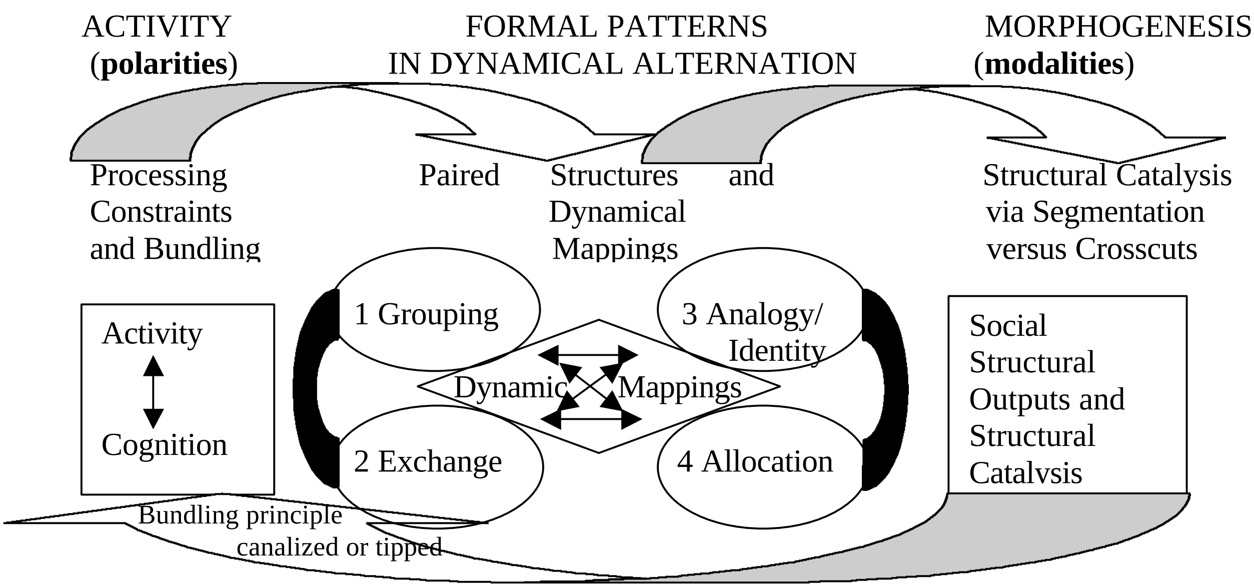
1) **Structural catalysis** (the term catalysis refers to the regulation of processes through slowing down or speeding up their temporal rates or contracting/diffusing their temporal scales) is the emergence of shared perception, language, and autoregulatory communication, which requires or presupposes the emergence of a perceptible formal pattern of a social field such as the four pattern principles in networks of relations. These patterns (Table 1) provide not only a basis for perceptibility, but comprehend the principal forms that such formal patterns can take. Pattern 1 is fundamental to the grouping principle. Pattern 2 is the essential basis for understanding exchange (Gregory 199_?, Bell 199_?). Pattern 3 is fundamental to thought, narrative structure, the 'situatedness' of intelligibility (Hofstadter 199_, and Falconnier 199_) and the recognition process in social identity, role, and attributed motivation and reputation (Harrison White 199_ and others). Pattern 4 is the recognized basis of formal organizations, office holding and the allocation of responsibility.
2) **Tipping points** (Gladwell 2000) occur in historical trajectories where, although networks are still composed of the same types of relations, the way that the relations are distributed across formal structural patterns (and functions) is dramatically altered. Structural catalysis may alter which kinds of relations are utilized as the basis of grouping, and which as the basis of exchange. Similarly for how relations are distributed in the logic of analogy/identity and the logic of allocation.
3) **Interdependence** among the four pattern principles in Table 1 occurs in **pairings**: the grouping logic of relational solidarity is paired with an exchange logic between groups (which are not however automatically solidary); and the analogous-positions logic in a behavioral system is paired with the formal or organizational activity allocation logic (but these two logics are not necessarily well coordinated).
4) **Modalities** by which the pairs of pattern principles (1 and 2; 3 and 4) are articulated are segmentation (as in homomorphic equivalence classes) and crosscutting integration (as in cohesive blocking and set intersection). Further, if the pairings are in perfect alignment they are more likely to neatly **segment** and/or segregate a social field (and its perceptual and communicative superstructures); if they are in misalignment they **crosscut** and thereby integrate a field through overlap, nuance and ambiguity.
5) **Morphogenesis** as an aspect of coherence results from the fact that the segmentary versus crosscut patterns, among others, have very different and very severe implications and consequences (they strongly affect the path dependence of evolution and historical trajectories). The PI's dissertation (White 1969) established through comparative ethnographic analysis that morphogenic coherence occurs between the degree of crosscut integration in a social structure and the degree of cooperativity required in the labor processes. One of his student's dissertations (Grannis 1998) established the converse for urban systems: the greater the segmentation of transport and communication systems into tree-like structures with cul-de-sacs, the lower the indices of social integration and cooperativity.
6) **Bundling** of activities in ways that satisfy easily executable behavioral routines is a necessary feature of spatiotemporal and sociocognitive (shared information) systems (Goodenough 197_ develops this into a principle of cultural organization and dynamics). Morphogenic and network pattern principles come to bear on this fundamental organization problem. Coherence in the expressive behavior, because of activity and cognitive constraints similar to those that require bundling, also requires high coherence in coordinate mapping with the labor domain. Hence:

7) **Polarity reduction** occurs between activity and cognition, and between expressive and task behavior (one has to see the films of Alan Lomax to recognize the coherence between them) as they are brought into coherent interdependence. In this process, for example, significant low frequency activities (e.g., mortuary ceremonies) are brought into resonance or synchronization with high frequency ones (e.g., daily or seasonally recurrent activities).
8) **Structural catalysis** again (the emergence from a perceptible formal pattern of a field of perception, language, and autoregulatory communication) plays a role in bundling and polarity reduction. For example, analogous conceptual structures (pattern principle 3) map onto diverse activity sets, and 'unify' them culturally. Similarly, formal principles of political, organizational and task allocation (pattern principle 4) require synchronization through structural catalysis of principles of recruitment, succession and inheritance with activity and autoregulation processes.
9) From smallest details up to the largest of abstract patterns of activity, **structural catalysis** is at work on different spatiotemporal and sociocognitive scales, that is, in a temporal and spatial spectrum, and in a social and cognitive spectrum of process. This is what dynamicist Iberall (19..) calls the stack of 'factory day' processes that make up the spectra of activities of any complex system.
10) the two sets of principles (1&2 vs 3&4) are articulated by dynamic mappings some of which involve further individuated network attributes such as centralities and diversity in other attributes that serve as the basis for recruitment, etc. [[FN. here we might add **Centralities -** Within the group-level hierarchies of cohesion and adhesion there is room for further variability at the individual and subgroup level, including variability in relative centrality of nodes or subgroups. Centrality structures are constrained, however, by levels of cohesion and adhesion. A star pattern of maximal centralization, for example, can occur where adhesion is high but cohesion is low, whereas high cohesion (which entails high adhesion as well) places a limit on centralization.]]

In the previous NSF research, parts of this framework were used successfully to analyze network data in a variety of field settings: our four-village Tlaxcalan study (White et al. 2001), our Austrian village study (Brudner and White 1997), the Turkish nomad study (Johansen and White 2001) , etc. In the process of diffusing the framework through methodological workshops, the PI was invited to join three major research projects that had extensive historical or time-series data: **the Florentine banking project (Padgett), the Biotech industry project (Powell), and the European settlement and communication structure or Archaeomedes project (van der Leeuw).** Having established the usefulness of the formal analysis of cohesive and adhesive structures as a component of systems integration, the present research is able to turn to the problems of dynamics in terms of how the grouping principles fit into a larger framework of theoretical analysis.

Concepts D: Dynamics

Figure 2 summarizes the hypotheses and puts them in a dynamical context. In addition to tipping points in the assortment of relations across formal structural patterns, one of the principal sources of dynamical instability occurs in the variable ways that the coarser grouping and group exchange formal patterns are mapped onto the more nuanced logics of analogy and allocation.



All mediated by the environment?

Figure 2: Process Model of Relational Coherence between Statics and Dynamics

An example of segmentation is the Tikopia or Anuta, where an exogamous patriclan is segmented by an internal marriage…. We are now rewriting a book on these two cases with an explanation as to how a pseudo-dual structure can fit with segmentation.

The Turkish nomads are an opposite example, where the patriclan is an endogamous deme

Congruence, but also tipping points

AJS study exemplifies …

Collaborations
Wille – Burmeister
Van der Leeuw - Sanders
Powell – Koput
Padgett – Newman
Le Bras - Cristofoli

Applications A:
Florentine
Nord-Pas-de-Calais
Norfolk
Archaeological - European
new students: Bridgit Paulztat, Shellie Masri, Cynthia Veit, Greek/Egyptian guy
email to Pauline Manaka http://eclectic.ss.uci.edu/~drwhite/center/cac.html

Applications B:

Applications C:

Project Publications: A. Web and CD-ROM Publications

1. 1999 Douglas R. White, Michael Schnegg, Lilyan Brudner. The Invisible State: Radial Cohesion in Tlaxcala, Mexico. http://eclectic.ss.uci.edu/~drwhite/cases/decentralized.html

2. 2000 Robert V. Kemper, Eric Widmer, Douglas R. White. From Tarascan Empire to Craft Production: A longitudinal research web-site (Tzintzuntzan, Mexico). http://www.santafe.edu/tarasco

3. 2000 Douglas R. White. Computational Anthropology, Informatics and Related Sciences. http://eclectic.ss.uci.edu/~drwhite/center/cac.html.

B. Books and Articles

4. 1999 Douglas R. White, Vladimir Batagelj and Andrej Mrvar, "Analyzing Large Kinship and Marriage Networks with Pgraph and Pajek," Social Science Computer Review 17:245-274.

5. 1999 Douglas R. White. "Elementary Simulation of Marriage Systems." Journal of Artificial Societies and Social Simulation 2(3). http://jasss.soc.surrey.ac.uk/2/3/5.html

6. 2001 Douglas R. White and Ulla Johansen. An Introduction to Network Analysis of Genealogy and Politics: Social Dynamics in a Nomadic Society. Lexington Press.

7. In Press Ulla Johansen, Douglas R. White. "Long-term Ethnography and the Collaborative Study of Social Dynamics in a Nomadic Clan in Southeastern Turkey," Long-term Ethnographic Research, eds. Robert V. Kemper and Anya Royce, Altamira Press.

8. In Press Frank Harary, Douglas R. White "P-Systems: A Structural Model for Kinship Studies." Connections, journal of the International Network for Social Network Analysis.

9. In Press Douglas R. White, Frank Harary. "The Cohesiveness of Blocks in Social Networks: Connectivity and Conditional Density." Sociological Methodology 2001.

10. Douglas R. White, Frank Harary. "Collective Geodesics and Co-evolution: A Graph Theoretic Model." Advances in Complex Systems.

11. In review James Moody, Douglas R. White. "Social Cohesion and Embeddedness: A Hierarchical Conception of Social Groups." Santa Fe Institute Working Paper 00-08-049, http://www.santafe.edu/sfi/publications/Working-Papers/00-08-049.pdf.

12. In review Douglas R. White, Mark Newman. "A Fast Algorithm for Node-Independent Paths." Sociological Methodology 2002.

13. In process Powell, Walter W., Douglas R. White, Kenneth W. Koput and Jason Owen-Smith. “Evolution of a Science-Based Industry: Dynamic Analyses and Network Visualization of Biotechnology,” submitted to American Journal of Sociology.

14. In process Douglas R. White, Michael Houseman. "Sidedness: 60 Million Strong." American Anthropological Association Annual Meeting 2001.

15. In process Douglas R. White. “Emergence, transformation and decay in socio-natural systems.” In *Emergence, Transformation and Decay in Socio-Natural Systems*, eds. Sander van der Leeuw, Uno Svedin, Tim Kohler, Dwight Read.

C. Student Dissertations and Articles

16. Alcantara-Valverde, Narda. 2000. *Kinship and Friendship Networks in Mexican Politics: Between Elite Interlocking and Faction Formation.* Ph.D. Dissertatio ,,School of Social Sciences, Irvine (Douglas R. White, Chair).

17. Casasola, Silvia, and Narda Alcántara. 1999. Elite Family Networks in 18th Century Guatemala. To appear in, Jorge Gil and Samuel Schmidt, eds. *Social Networks: Theory and Applications*.

18. Fitzgerald, William, and Douglas R. White. 1998. Class Differentiation and Structural Endogamy in the Bevis Marks Synagogue, London. Manuscript.

19. Skyhorse, Patricia. 1999. Adoption as a Strategy on a Chuukese Atoll. *The History of the Family* 3:429-439.

References

Gladwell, Malcolm. 2000. *The Tipping Point: How Little Things Make a Big Difference*. Boston: Little, Brown.

Hutchins, Edwin. 1996**. *Cognition in the Wild***. Cambridge: MIT Press.

Lorrain and White 1970

Moore, Alexander. 1998. *Cultural Anthropology: The Field Study of Human Beings*. San Diego: Collegiate Press.

Ganter, Bernard, and Rudolf Wille. 1999. *Formal Concept Analysis: Mathematical Foundations*. New York: Springer Verlag.

Gil Mendieta, Jorge, Samuel Schmidt, Jorge Castro, and Alejandro Ruiz. 1999, *La Red Política de México: modelacíon y analysis por medio de la teoria de grafos. México***, D.F.:** Laboratorio de Redes del Departamento de Modelacion Matematica de Sistemas Sociales del Instituto de Investigaciones en Matemáticas Aplicadas y en Sistemas de la Universidad Nacional Autonoma de Mexico. Data Base REDMEX.

Harary, Frank. 1983. Conditional Connectivity. *Networks* 13:437-357.

---1984. Conditional Colorability. *Graph Theory Singapore 1983.* Lecture Notes in Mathematics 1073:127-36.

Houseman and White. 1996. Structures réticulaires de la pratique matrimoniale. *L’Homme* 139:59-85.

--- 1998a. Network Mediation of Exchange Structures: Ambilateral Sidedness and Property Flows in Pul Eliya. In T. Schweizer and D. R. White, eds., *Kinship, Networks and Exchange*. Cambridge: Cambridge University Press. Pp.59-85.

--- 1998b. Taking Sides: Marriage Networks and Dravidian Kinship in Lowland South America. Pp. 214-243, in Maurice Godelier, Thomas Trautmann, and Franklin E. Tjon Sie Fat, eds., *Transformations of Kinship*. Smithsonian Institution Press.

Padgett, John. forthcoming. Organizational Genesis, Identity and Control: The Transformation of Banking in Renaissance Florence. In, *Networks and Markets*, James E. Rauch and Alessandra Casella, eds.

Padgett, John, and Christopher J. Ansell. 1993. Robust Action and the Rise of the Medici. *American Journal of Sociology* 98:1259-1319

White, Douglas R. 1997. Structural Endogamy and the Graphe de Parenté. *Informatique, Mathématique et Sciences Humaines* 137:107-125. http://eclectic.ss.uci.edu/knhe/str-endo.htm.

Berkowitz, Stephen D. 1982. *An Introduction to Structural Analysis: The Network Approach to Social Research*. Toronto: Butterworth.

Brudner, Lilyan A. and Douglas R. White. 1997. “Class, Property and Structural Endogamy: Visualizing Networked Histories.” *Theory and Society* 25:161-208.

Burt, Ronald. 1982. *Toward a Structural Theory of Action*. New York: Academic Press.

Burt, Ronald. 1992. *Structural Holes*. Chicago: University of Chicago Press.

Freeman, Linton. 1996. “Cliques, Galois Lattices, and the Structure of Human Social Groups.” *Social Networks* 18:173-187.

Freeman, Linton and Douglas R. White. 1993, "Using Galois Lattices to Represent Network Data." *Sociological Methodology 1993*, pp. 127-146, Peter Marsden, ed.

Knoke, David. 1990. *Political Networks: The Structural Perspective*. Cambridge: Cambridge University Press.

Knoke, David and James Kuklinski. 1982. *Network Analysis*. Beverly Hills: Sage.

Mitchell, J Clyde (ed.). 1969. *Social Networks in Urban Situations*. Manchester: Manchester University Press.

Mullins, Nicholas. 1973. *Theories and Theory Groups in Contemporary American Sociology*. New York: Harper and Row.

Reitz, Karl and Douglas R. White. 1989. "Rethinking the Role Concept: Homomorphisms on Social Networks," pp. 429-488 in *Research Methods in Social Network Analysis*. L. C. Freeman, D. R. White, A. K. Romney eds., George Mason Press.

Rogers, Everett and D. Lawrence Kincaid. 1981. *Communication Networks*. New York: Free Press.

Scott, John. 1991. *Social Network Analysis*. London: Sage.

Snijders, Tom and Roel J. Bosker. 1999. *Introduction to Multilevel Analysis*. London: Sage.

Tilly, Charles. 1984. *Big Structures, Large Processes, Huge Comparisons*. New York: Russell Sage Foundation.

Wasserman, Stanley and Katherine Faust. 1994. *Social Network Analysis: Methods and Applications*. Cambridge: Cambridge University Press.

Wellman, Barry. 2000. Networking Network Analysts: How INSNA (the International Network for Social Network Analysis) Came to Be. *Connections* 23(1): 1-31.

Wellman, Barry and S.D. Berkowitz (eds.). 1988. *Social Structures: A Network Approach*. Cambridge: Cambridge University Press.

White, Douglas R., Michael Schnegg, Lilyan A. Brudner and Hugo Nutini. 1999. Networked Integration: Multiple Connectivity and its Crosscutting Boundaries in Tlaxcalan Kinship and *Compadrazgo*. To appear in, Jorge Gil and Samuel Schmidt, eds. *Social Networks: Theory and Applications.*

White, Douglas R. and Karl P. Reitz,.1983. Graph and Semigroup Homomorphisms." *Social Networks* 5:193-234.

White, Douglas R. and Thomas Schweizer. 1998. “Kinship, Property and Stratification in Rural Java.” In T. Schweizer and D.R.White, eds., *Kinship, Networks and Exchange*. Cambridge: Cambridge University Press. Pp.36-8.