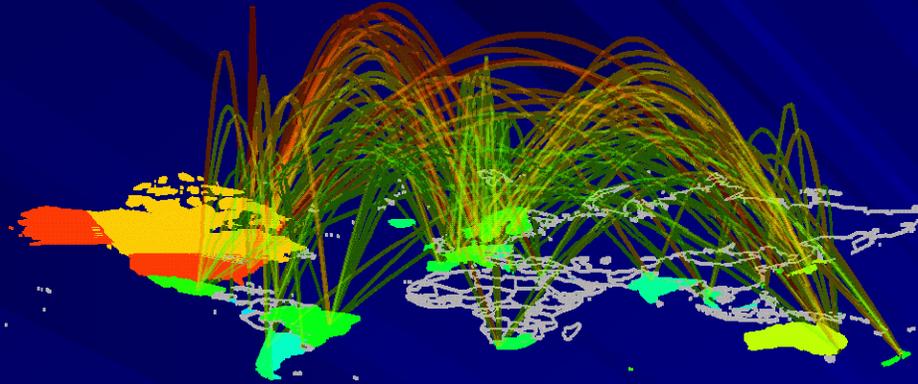Network diagram by Alden Klovdahl, Australian National University

Social Network Analysis: Overview of the Field Today

Steve Borgatti

BOSTON COLLEGE

Agenda

- SNA as a discipline
- Introduction to the field
- Critical assessment
- Frontier

Painting by Idahlia Stanley

Formal Organization of the Field

- **Professional association (since '78)**
  - Int'l Network for Social Network Analysis - www.insna.org
  - Incorporated 1993
- **No Department of Social Network Analysis**
  - But some centers for complexity and networks

- **Sunbelt annual conference (since '79)**
  - 2001: Budapest, HUNGARY
  - 2002: New Orleans, USA
  - 2003: Cancun, MEXICO
  - 2004: Portorôs, SLOVENIA
  - 2005: Los Angeles, USA
  - 2006: Vancouver, CANADA
  - 2007: Corfu, GREECE

Resources of the Field

Specialized journals
- *Social Networks*, (since '79)
- *CONNECTIONS*, official bulletin of INSNA
- *Journal of Social Structure* (electronic)
- CMOT

Textbooks
- Kilduff & Tsai, 2004
- Scott, John. 1991/2000.
- Degenne & Forsé. 1999.
- Wasserman & Faust. 1994.

Software
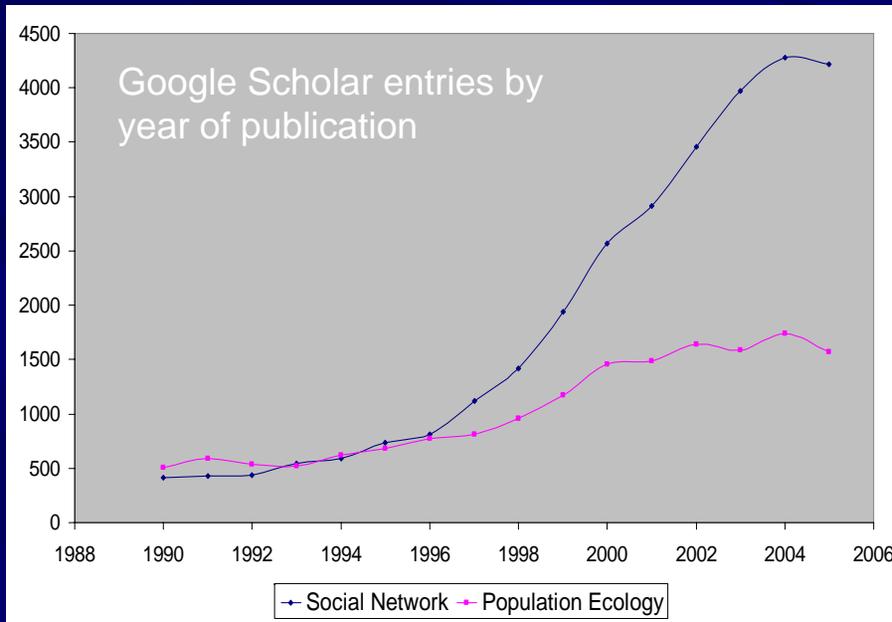- UCINET 6/NETDRAW; PAJEK
- STRUCTURE; GRADAP; KRACKPLOT

Listservs
- SOCNET listserv (1993)
- REDES listserv
- UCINET user's group
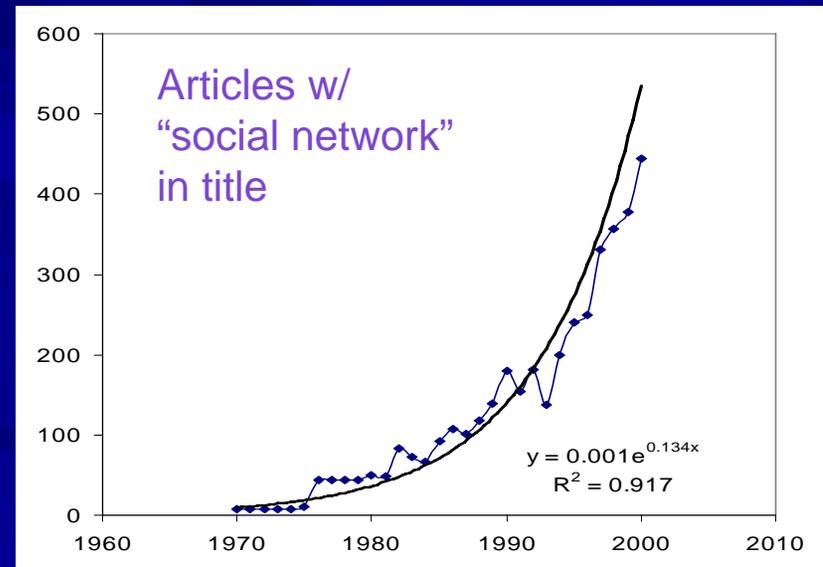
Regular Training Workshops
- Sunbelt social networks conference
- Academy of Management
- University of Essex, UK
- ICPSR-Michigan

Explosive Growth

Google Scholar entries by year of publication

4500
4000
3500
3000
2500
2000
1500
1000
500
0

1988 1990 1992 1994 1996 1998 2000 2002 2004 2006

Social Network — Population Ecology

- Google page rank
- Social networking software
- Management consulting
- Network organizations

- Embeddedness, social capital, structural holes, alliances
- TCE, RD, Inst theory, SRT, etc

Articles w/ "social network" in title

600
500
400
300
200
100
0

1960 1970 1980 1990 2000 2010

$y = 0.001e^{0.134x}$
$R^2 = 0.917$

Development of the Field

- **1900s**
  - Durkheim
  - Simmel
- **1930s Sociometry**
  - Moreno; Hawthorne studies
  - Erdos
- **1940s Psychologists**
  - Clique formally defined
- **1950s Anthropologists**
  - Barnes, Bott & Manchester school
- **1960s Anthros & graph theorists**
  - Kinship algebras; Mitchell
  - Harary establishes graph theory w/ textbooks, journals, etc

- **1970s Rise of Sociologists**
  - <u>Modern field of SN is established</u> (journal, conference, assoc, etc)
  - Milgram small-world (late '60s)
  - White; Granovetter weak ties
- **1980s Personal Computing**
  - IBM PC & network programs
- **1990s Adaptive Radiation**
  - UCINET IV released; Pajek
  - Wasserman & Faust text
  - Spread of networks & dyadic thinking; Rise of social capital,
- **2000s Physicists' "new science"**
  - Scale-free
  - Small world

The New Science of Networks

What is distinctive about the field?

- The phenomena we study – i.e., the data
  - The observations (cases) are dyads, not individual actors
  - Fundamental variables are social relations (e.g., friendship) rather than attributes of individuals (e.g., education, personality)
  - Theoretical constructs like centrality, structural equivalence or network shape
- The methodology
  - Dyadic, autocorrelated data require different statistical methods
- Theoretical perspective
  - Not a single theory across all disciplines, but some common principles and perspectives

A Multi-layered Enterprise

- **Conceptual Layer**
  - Deepest metaphors
  - Taken for granted axioms
- **Technical Layer**
  - Graph theory
  - Theoretical vocabulary – network constructs
  - Methodology
- **Substantive Layer**
  - Network antecedents
  - Network consequences
 - Interface with other research streams

Conceptual Layer

- **Actors do not act independently**
  - Have ties of various kinds with other actors
- **Actors and ties link together to form networks**
  - Whether actors are aware of it or not
  - Pattern / arrangement of ties is discernable
- **Connectionist or flow-based axiom**
  - Diffusion and influence across links: actors affect each other
  - Access to resources through ties: social resource theory
- **Structuralist or topology-based axiom**
  - Structure of ties in the network has profound effects on the capabilities, constraints and ultimately outcomes of the network and its constituents
  - Bavelas-Leavitt work (1950s) on centralization of work teams

Ties as pipes

Ties as scaffolding

Relations vs. Attributes

- **Traditional soc sci focuses on actor attributes as explanatory variables**
- **Network science focuses on relations among the actors**
- **Influences & flows of Connectionist view**
  - Tell each other information
  - Provide material aid
  - Copy attitudes & behavior
  - Transmit diseases

Sexual relations among patients with rare cancers --- Bill Darrow, CDC

It's not just the parts but the structure

- Emergent, non-reductionist, non-individualist, holistic, structuralist flavor to <u>some</u> of the research
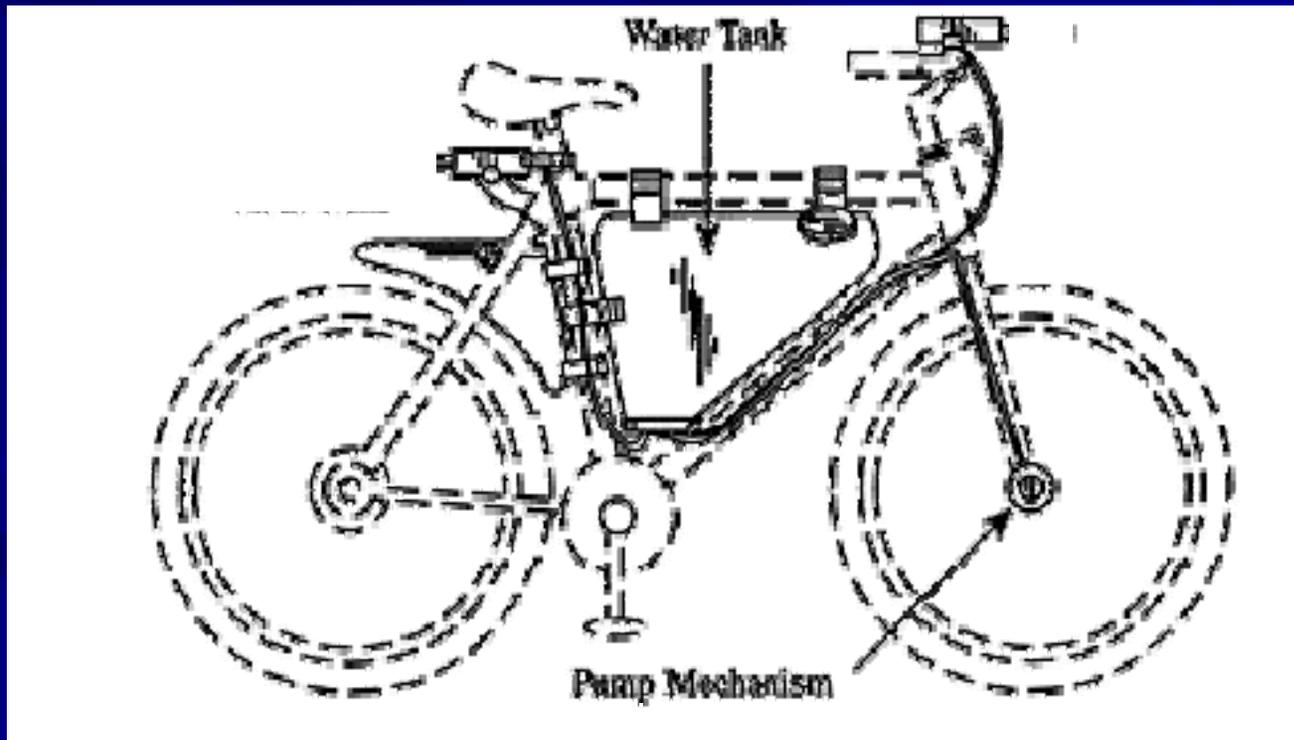
Opportunities & Constraints

■ A person's position in a social network (i.e., social capital) determines in part the set of opportunities and constraints they will encounter
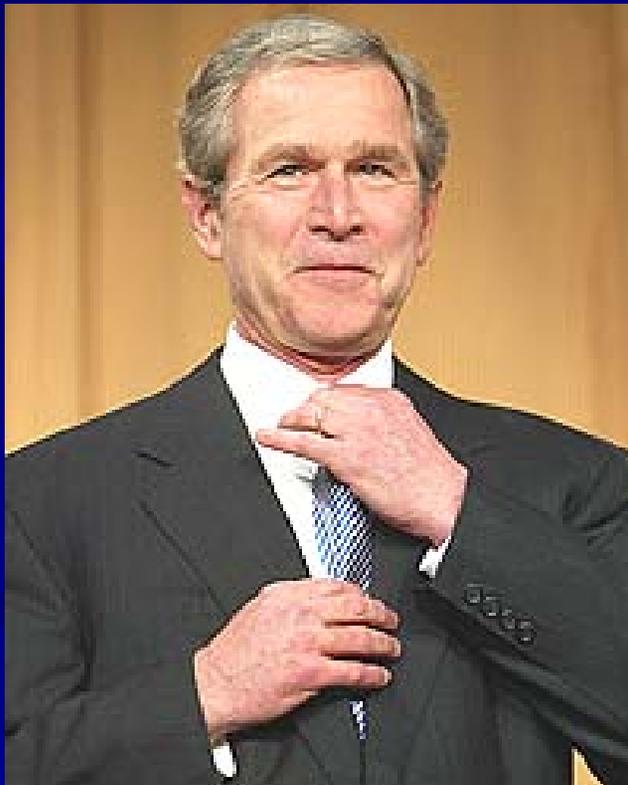
Rate of return on human capital

- Burt: A person's connections determine the rate of return on human capital

Human
capital

profit

rate of
return

social capital
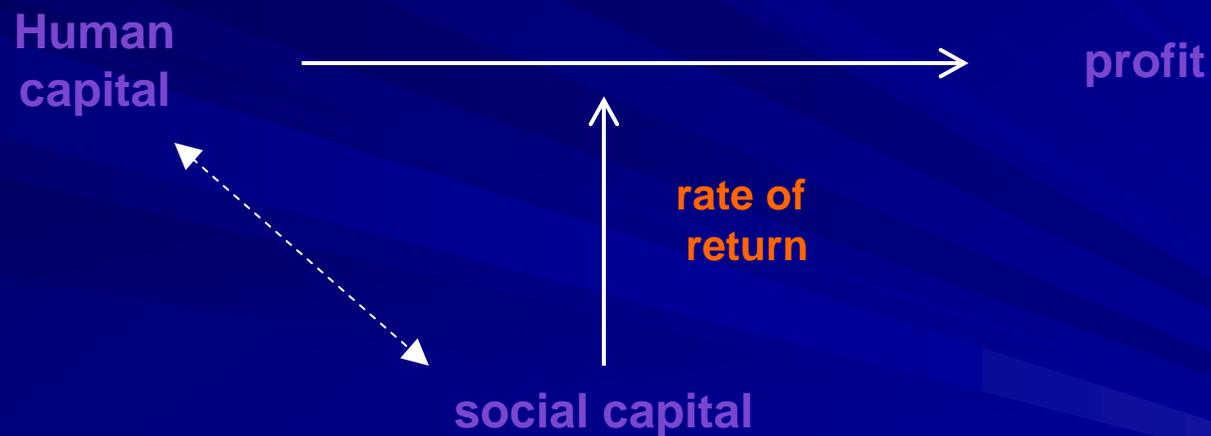
Universal network **laws?**

■ Similar network properties "observed" in

– Gene interaction networks

– World wide web links

– Sexual partners

$y = 185.98x^{-1.5152}$
$R^2 = 0.8699$

$y = 275.81x^{-1.7147}$
$R^2 = 0.9287$
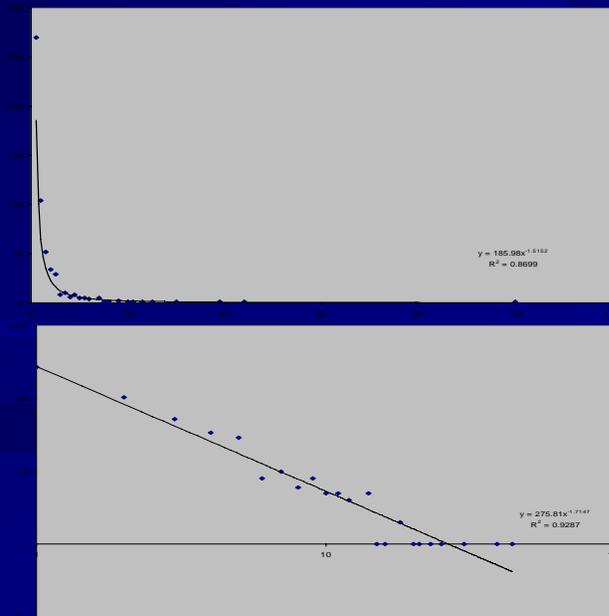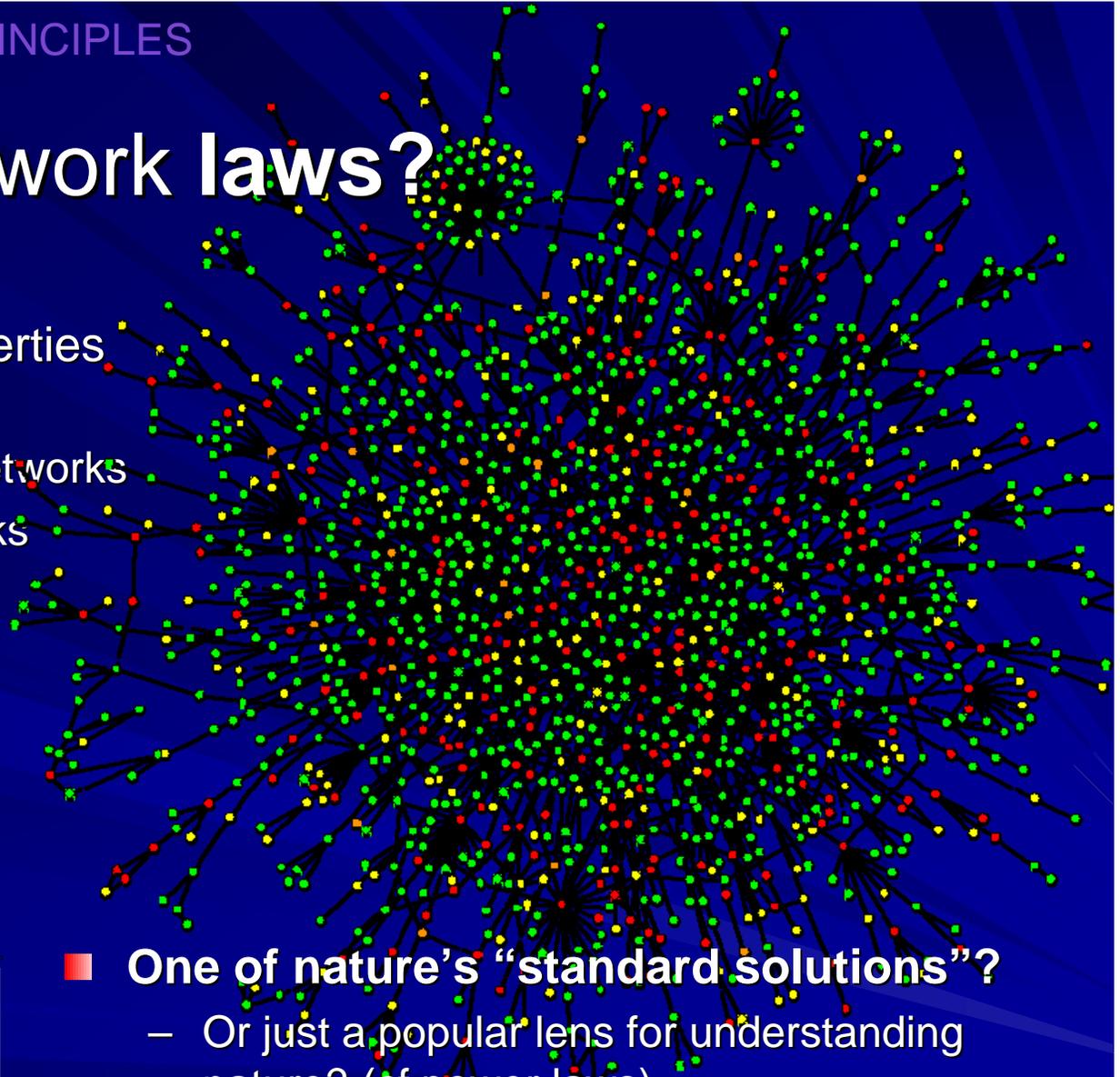
■ **One of nature's "standard solutions"?**

– Or just a popular lens for understanding nature? (cf power laws)

■ Warning: different social relations have different characteristic structures

Technical Layer

Key Constructs that are "good to think with"

What is a Network?

- A set of actors (nodes, points, vertices)
  - Individuals (e.g., persons, chimps)
  - Collectivities (e.g., firms, nations, species)
- A set of ties (links, lines, edges, arcs) that connect <u>pairs</u> of actors
  - Directed or undirected
  - Valued or presence/absence
- Set of ties of a given type constitutes a social relation
- Different relations have different structures & consequences
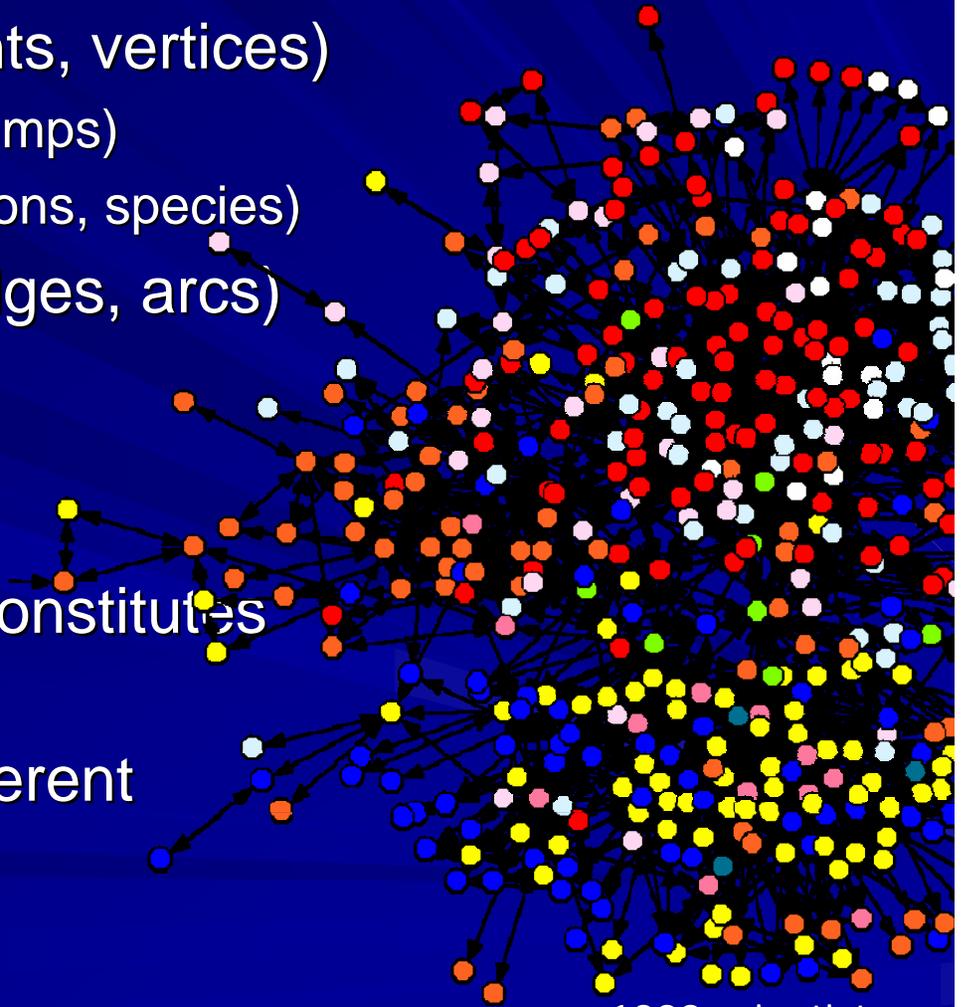
1000 scientists

Types of Tie Among Persons

- **Social relations**
  - Kinship
  - Other role-based
  - Cognitive
  - Affective
- **Correlations**
  - Co-membership
  - Similarity
  - Proximity

Roads

- **Interactions**
  - Sent email to, had sex with
  - Communicated with
- **Flows**
  - Personnel
  - Goods
  - Ideas/information
  - Infection
- **Influence**

Traffic

Each kind of tie (i.e., social relation) defines a different network

Simple Answers

Who you ask for answers to straightforward questions.

HR Dept
of Large
Health Care
Organization

🟢 Recent acquisition
🟠 Older acquisitions
🟡 Original company
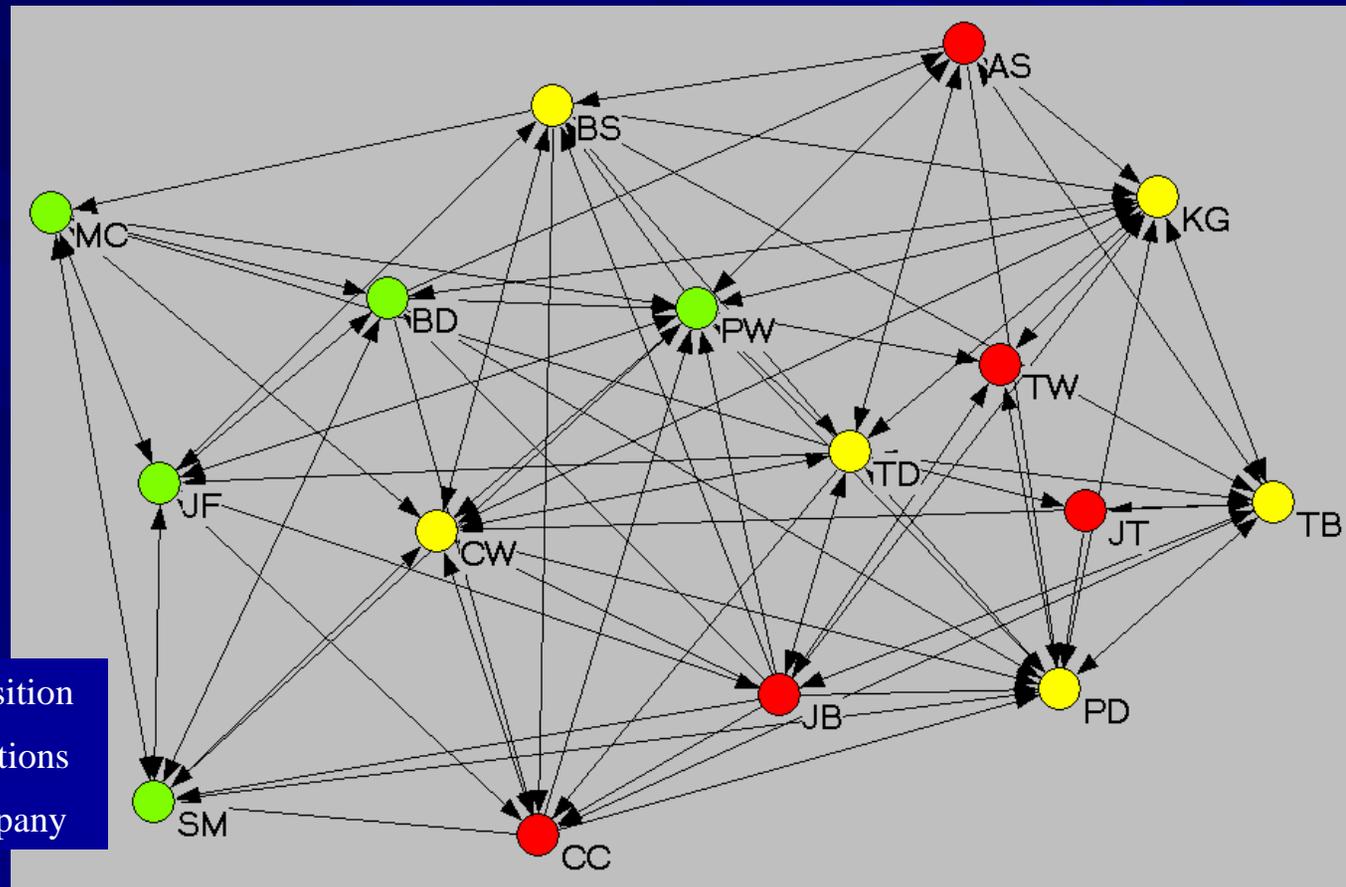
Cross, R., Borgatti, S.P., & Parker, A. 2001. Beyond Answers: Dimensions of the Advice
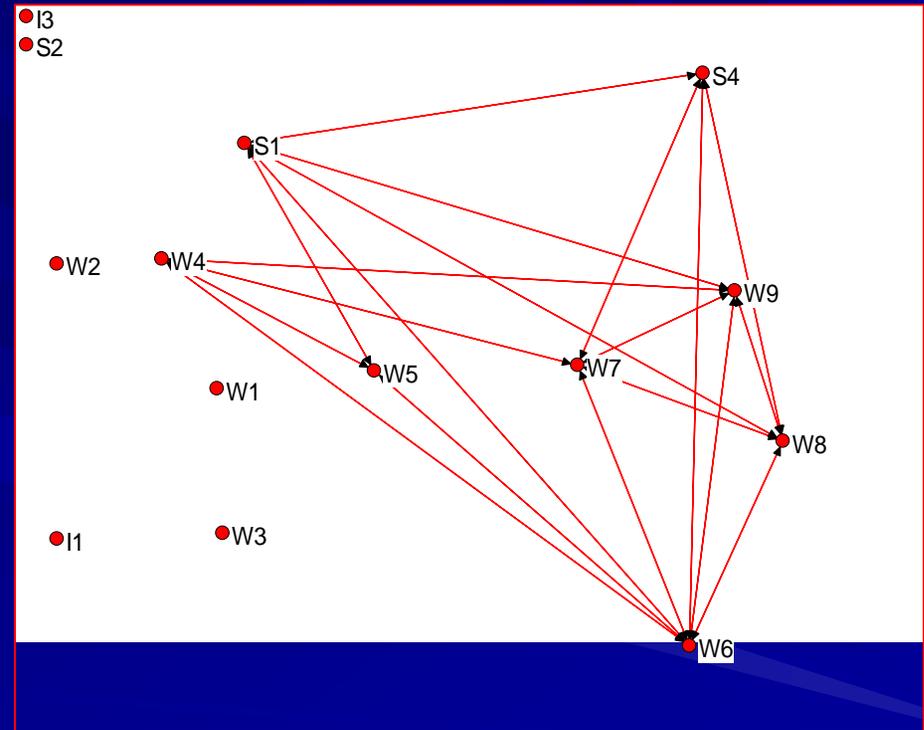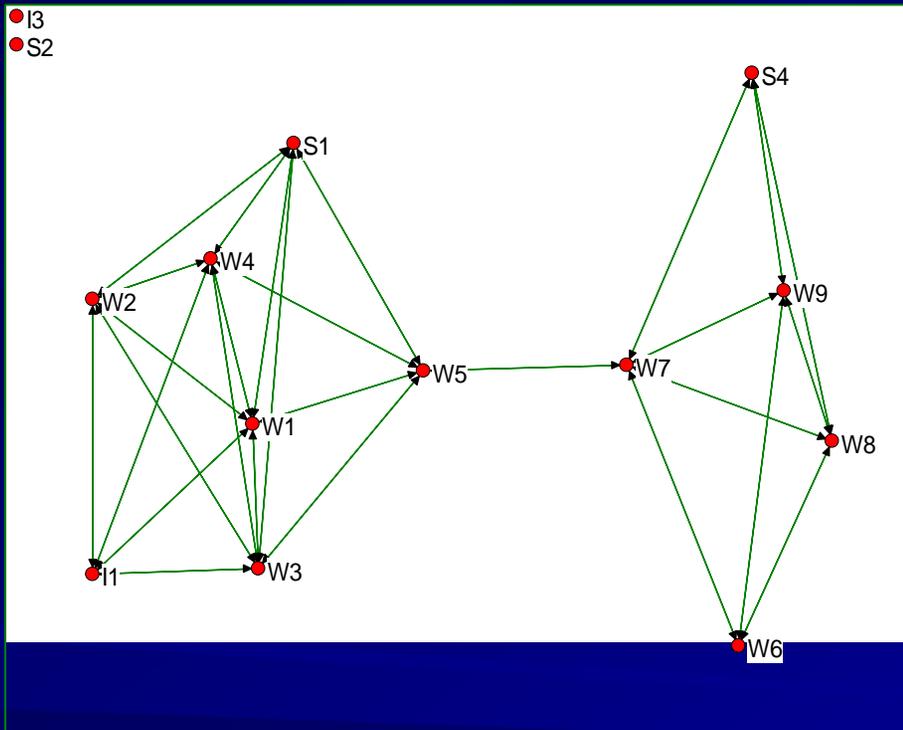Network. *Social Networks* 23(3): 215-235

Problem Reformulation

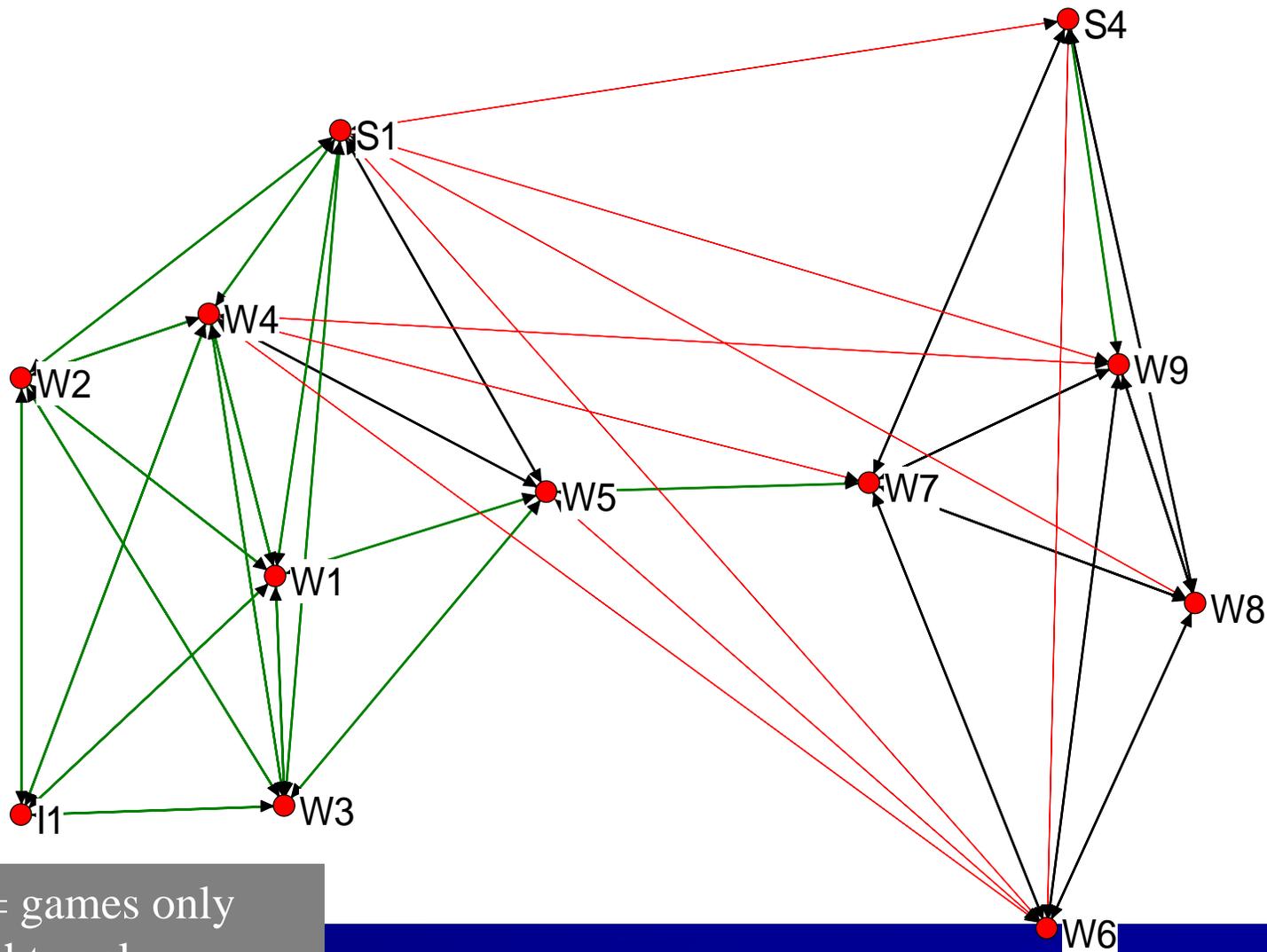Who you see to help you think through issues
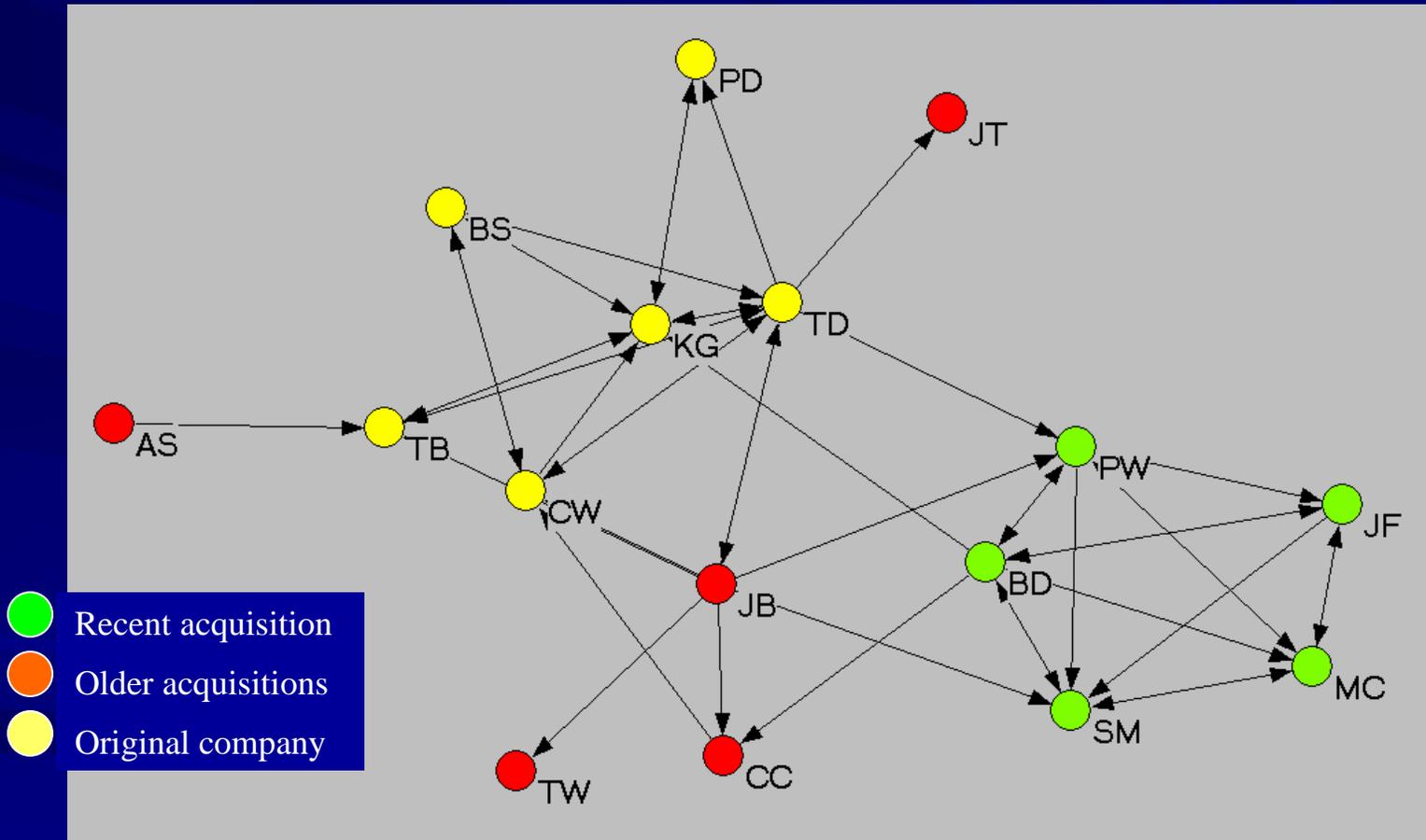
Recent acquisition

Older acquisitions

Original company

Cross, R., Borgatti, S.P., & Parker, A. 2001. Beyond Answers: Dimensions of the Advice Network. *Social Networks* 23(3): 215-235

Hawthorne Games & Conflicts
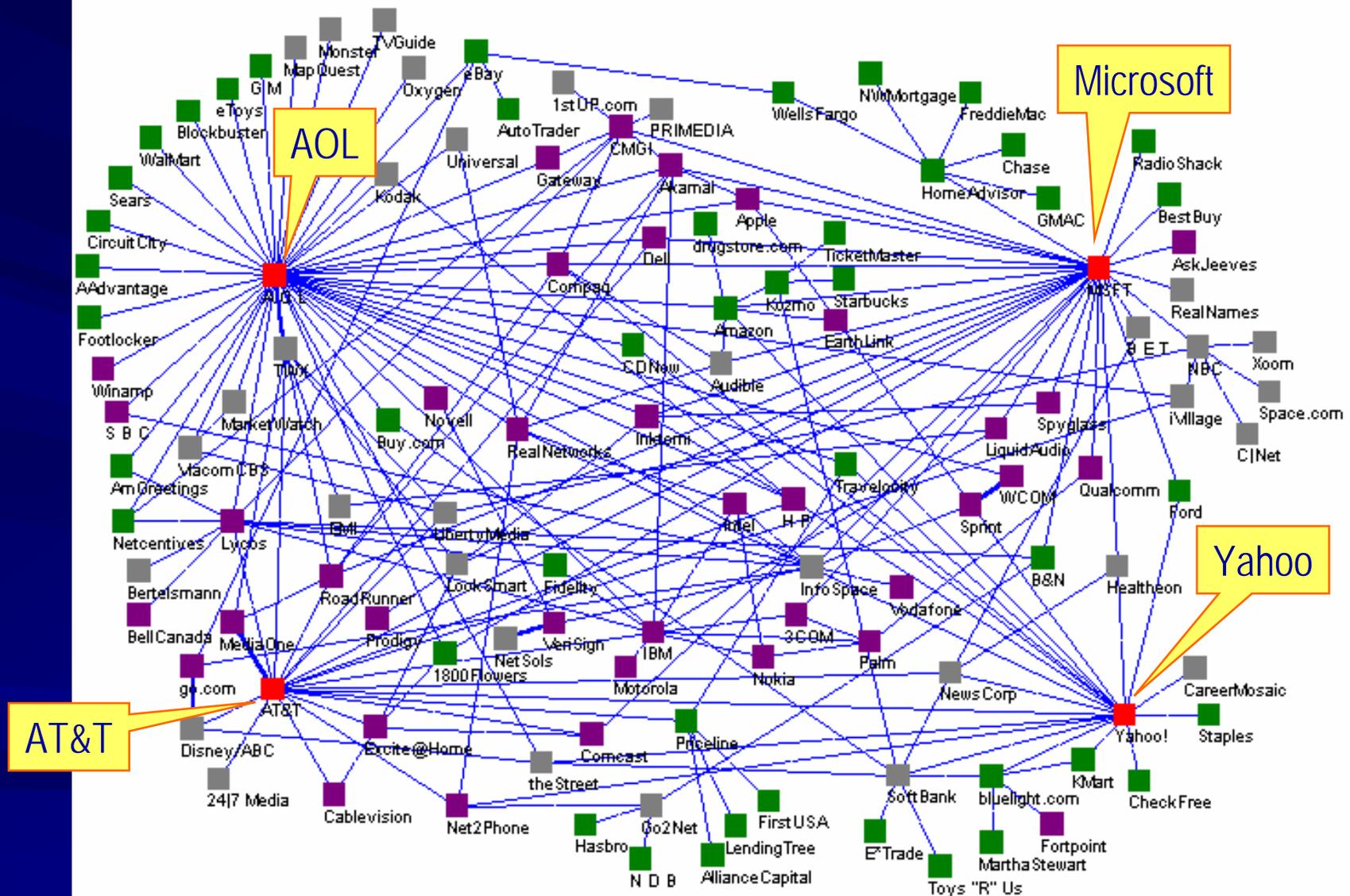
Combining Games & Fights

GREEN = games only
RED = fights only
BLACK = games & fights

Relations Among Organizations

- **As corporate entities**
  - sells to, leases to, lends to, outsources to
  - joint ventures, alliances, invests in, subsidiary
  - regulates
- **Through members**
  - ex-member of (personnel flow)
  - interlocking directorates
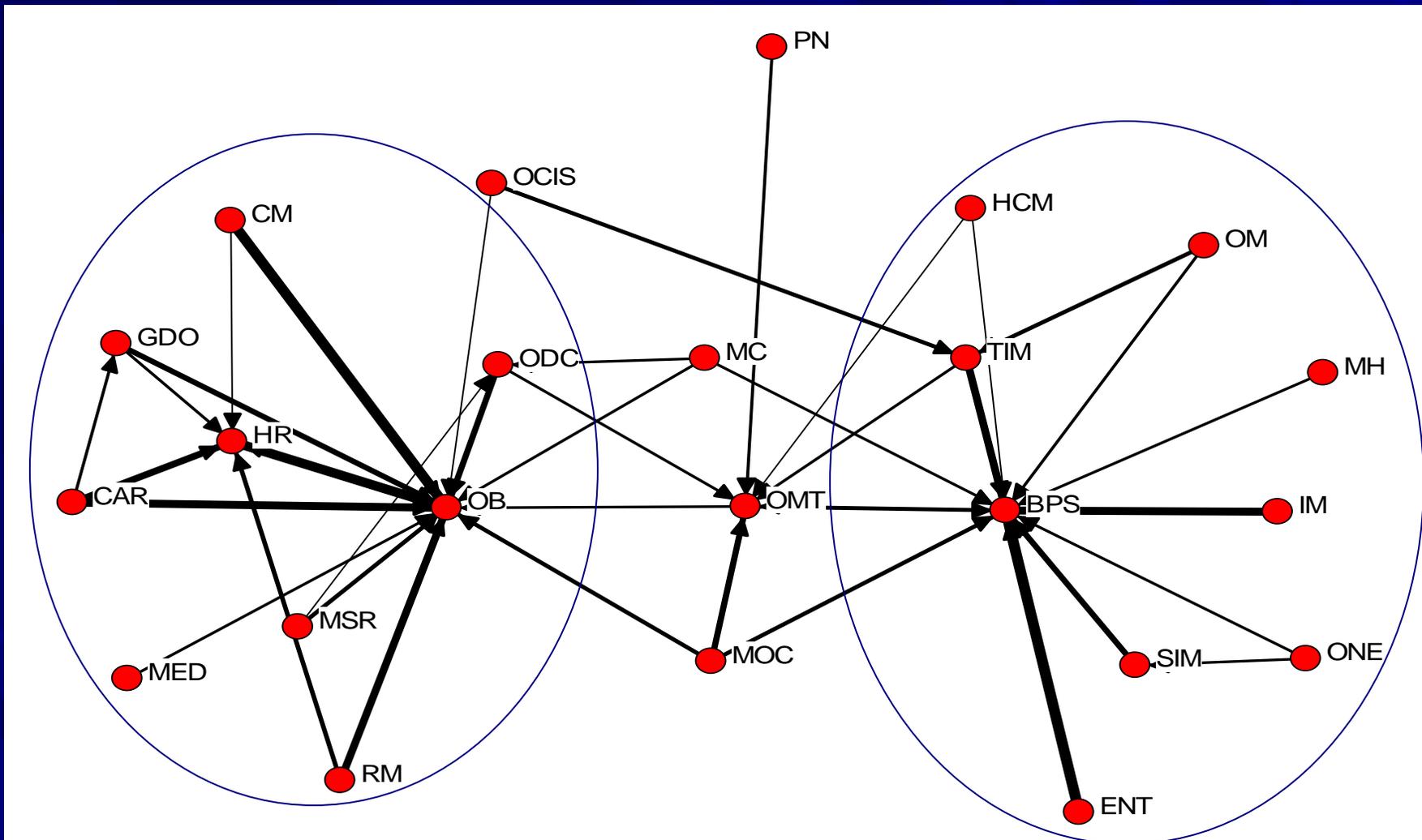 - all social relations

Internet Alliances

Consumer Internet

Copyright © 2000, Valdis Krebs

http://www.orgnet.com/netindustry.html

Co-Membership > 27%

Mainstream Logical Data Structure

- 2-mode rectangular matrices in which rows (cases) are entities or objects and columns (variables) are attributes of the cases
- Analysis consists of correlating columns
  - Typically identify one column as the thing to be explained
  - We explain one characteristic as a function of the others

Variables
(attributes)

Cases
(entities)

	Age	Sex	Education	Income
1001				
1002				
1003				
1004				
1005				
…				

Network Logical Data Structures

Adjacency matrices

Incidence matrix

Friendship

	Jim	Jill	Jen	Joe
Jim	-	1	0	1
Jill	1	-	1	0
Jen	0	1	-	1
Joe	1	0	1	-

Proximity

	Jim	Jill	Jen	Joe
Jim	-	3	9	2
Jill	3	-	1	15
Jen	9	1	-	3
Joe	2	15	3	-

	Friendship	Proximity
Jim - Jill	1	3
Jim - Jen	0	9
Jim - Joe	1	2
Jill - Jen	1	1
Jill - Joe	0	15
Jen - Joe	1	3

- Multiple relations recorded for the same set of actors
- Each relation is a variable
  - variables can also be defined at more aggregate levels
- Values are assigned to <u>pairs</u> of actors
- Hypotheses can be phrased in terms of correlations between relations
  - Dyadic-level hypotheses

Ego Network Analysis

Mainstream
Social Science

Ego
Networks

Network
Analysis
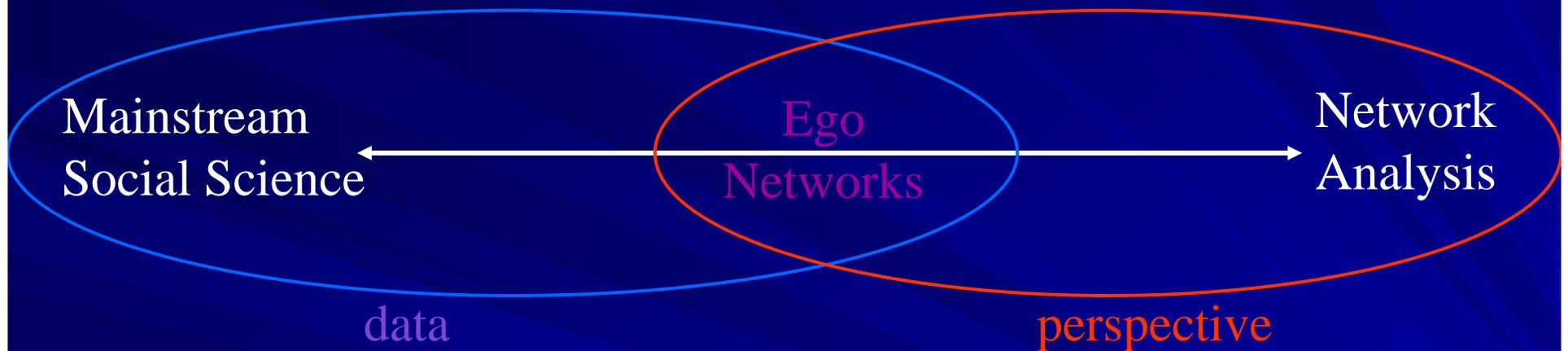
data

perspective

■ Combine the perspective of network analysis with the data of mainstream social science

Ego Network Data Collection

- (Random) survey of members of a population
- Ask respondents (egos) about their contacts (alters)
  - E.g., who they confide important matters with
- Characterize relationship with each alter
- Obtain attribute data about each alter (ego's perception)
- Optionally obtain ego's perception of which alters have ties with which other alters

Ego Network Analysis

- **Network composition assessments**
  - E.g., % women in each person's network
- **Selection: Investigating homophily / heterophily**
  - Do races prefer to marry endogamously?
  - Does eye color matter?
- **Network homogeneity / heterogeneity assessments**
  - How diverse is each person's network?
- **Network quality assessments**
  - Do entrepreneurs vary in their social access to resources?
- **Structural holes & other local density assessments**
  - Are my friends friends with each other?

Levels of Analysis

- **Dyad (relationship) level**
  - Network data is fundamentally dyadic
    - Who is friends with whom in an office
    - Distance in meters between people's desks
    - Marriage ties among families in Renaissance Florence
    - Business ties among the same families
- **Node (actor) level**
  - Can aggregate to the node level
    - The number of friends each person has
  - Or measure aspects of a node's position in the network
    - Betweenness centrality of each node
- **Network (group) level**
  - Aggregation to the group or whole network level
    - Density of ties within a group
  - Measure aspects of the network's structure
    - How centralized the network is; how concentrated the ties are around small set of actors

Families of Network Concepts

degree
distribution

core
periphery

clumpiness

avg distance
density

Shape

Cohesion

Group
level

degree

closeness

block

faction

clique

Centrality

Node
level

**Subgroup
identification**

**Role
identification**

Dyad
level

Proximity

Equivalence

adjacency

simmelian
tie

geodesic
distance

structural
equivalence

regular
equivalence

Presentation @ National Academy of Sciences

© 2005 Steve Borgatti

Density of ties

- Density = proportion of pairs of actors that are actually tied
- In some contexts, could be thought of as measure of **social capital**

Low Density (25%)
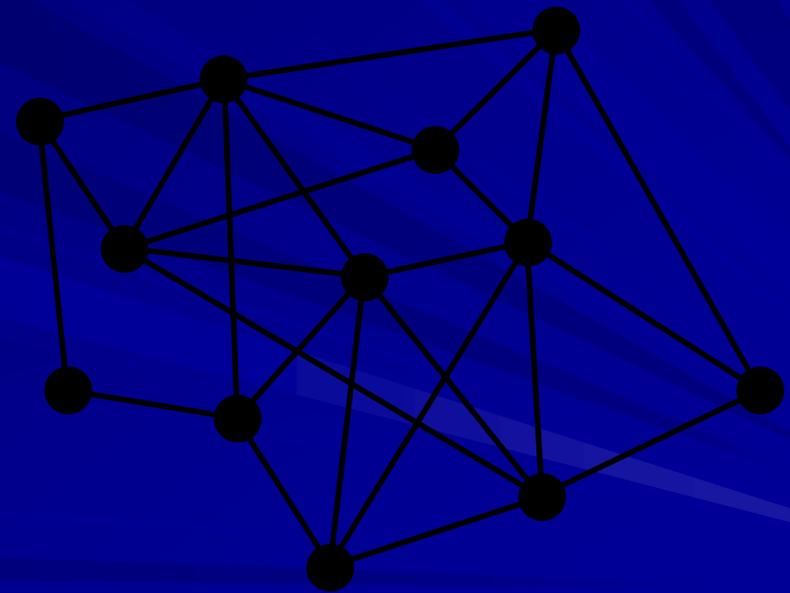
High Density (39%)

Help With the Rice Harvest
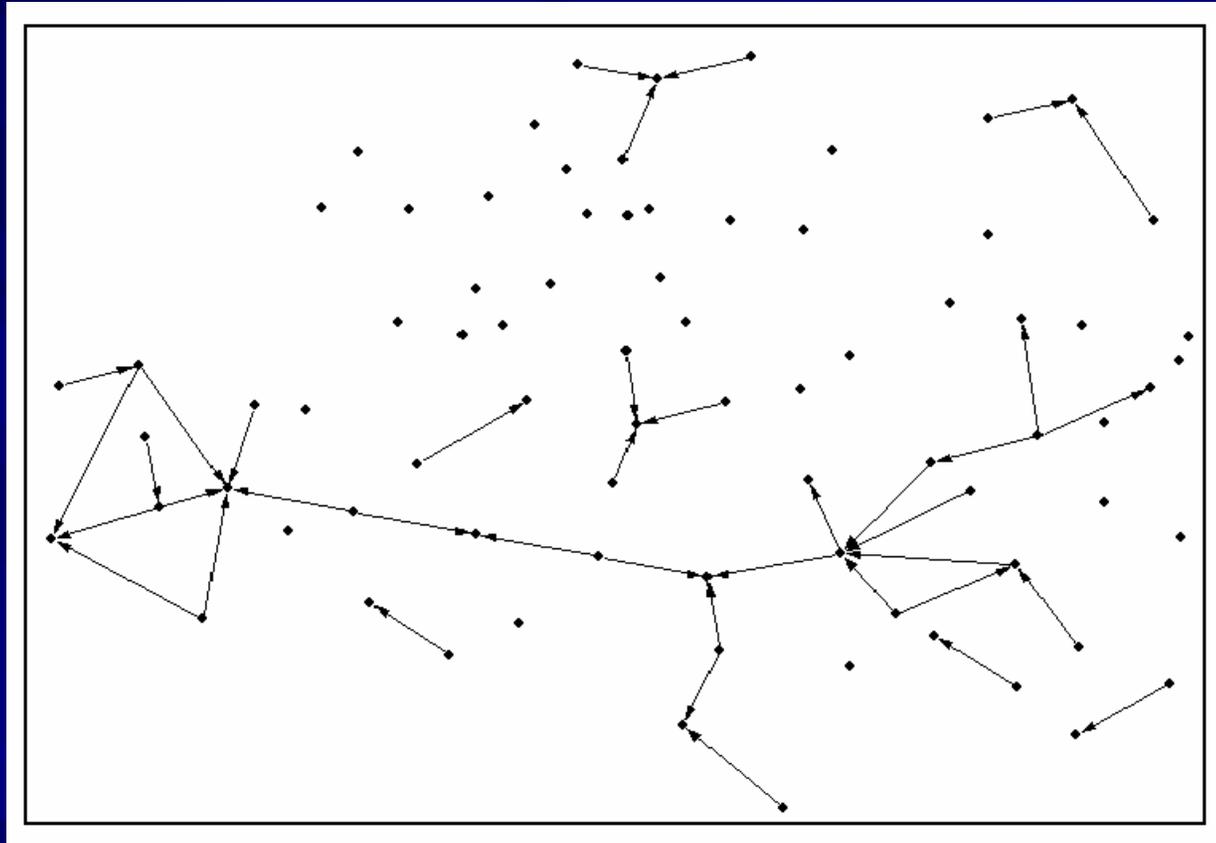
Village 1

Data from Entwistle et al

Help with the rice harvest
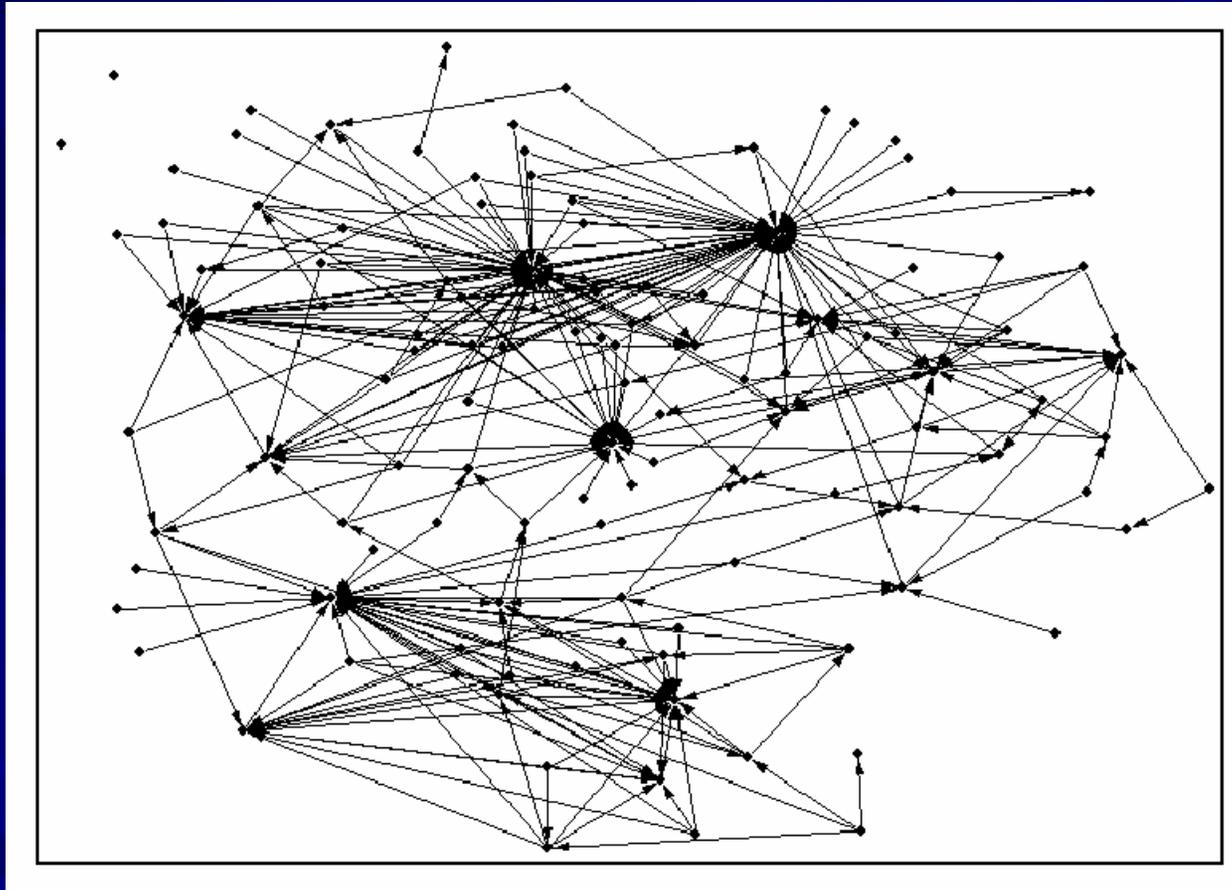
Village 2

Data from Entwistle et al

Graph-Theoretic Distance
AKA "degrees of separation"

- The graph-theoretic distance between two nodes is the number of links in the shortest path that connects them
  - Distance from 4 to 10 is 3 links
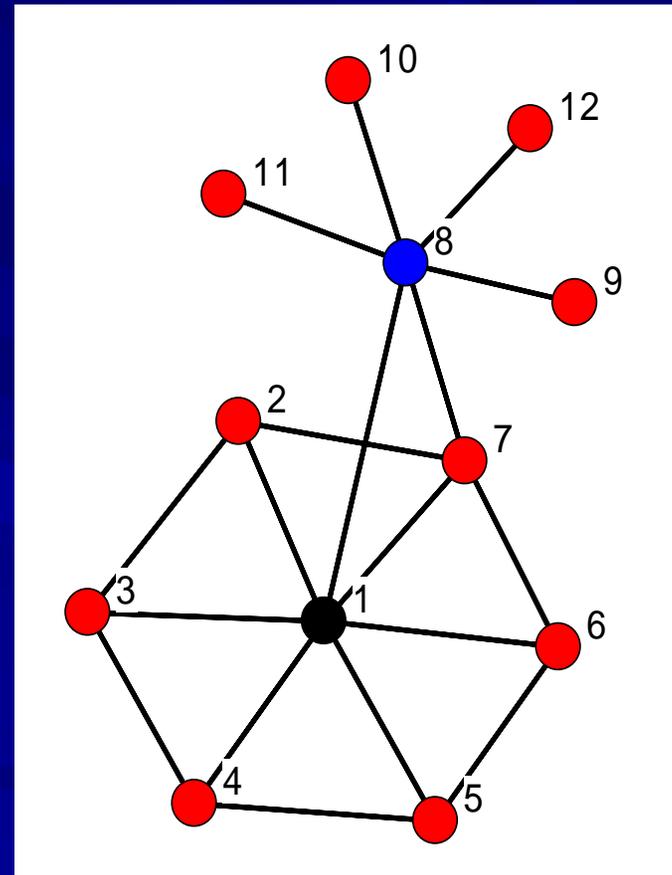
Core/Periphery Structures

■ Core/Periphery
- – Network consists of single group (a core) together with hangers-on (a periphery),
  - ■ Core connects to all
  - ■ Periphery connects only to the core
- – Short distances, good for transmitting information, practices
- – Identification with group as whole
- – E.g., structure of physics

■ Clique structure
- – Multiple subgroups or factions
- – Identity with subgroup
- – Diversity of norms, belief
- – E.g., structure of social science

C/P

Clique
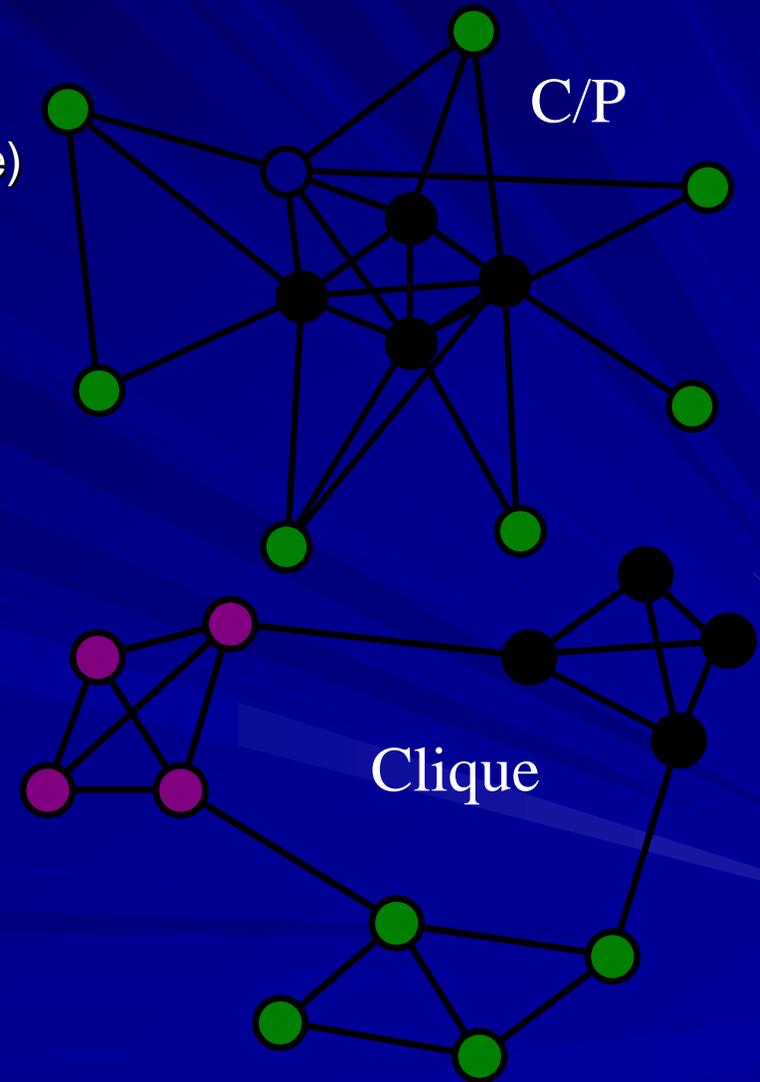
On Innovation and Network Structure

"I would never have conceived my theory, let alone have made a great effort to verify it, if I had been more familiar with major developments in physics that were taking place. Moreover, my initial ignorance of the powerful, false objections that were raised against my ideas protected those ideas from being nipped in the bud."

– Michael Polanyi (1963), on a major contribution to physics

C/P Structures & Morale

- Study by Jeff Johnson of a South Pole scientific team over 8 months

- C/P structure seems to affect morale

Core/Periphery-ness

Group Morale

Month
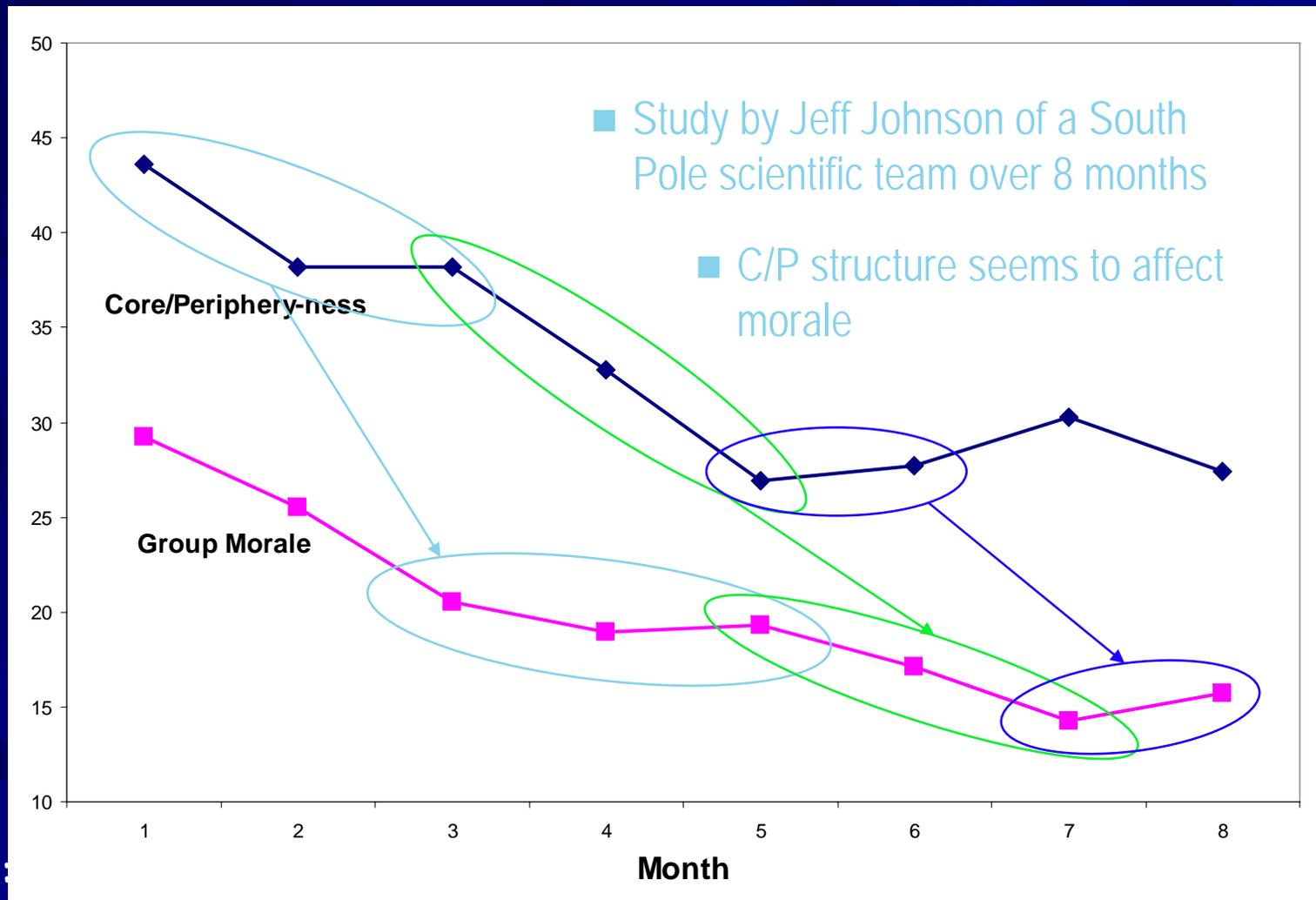
Caution:

Node Level Variables
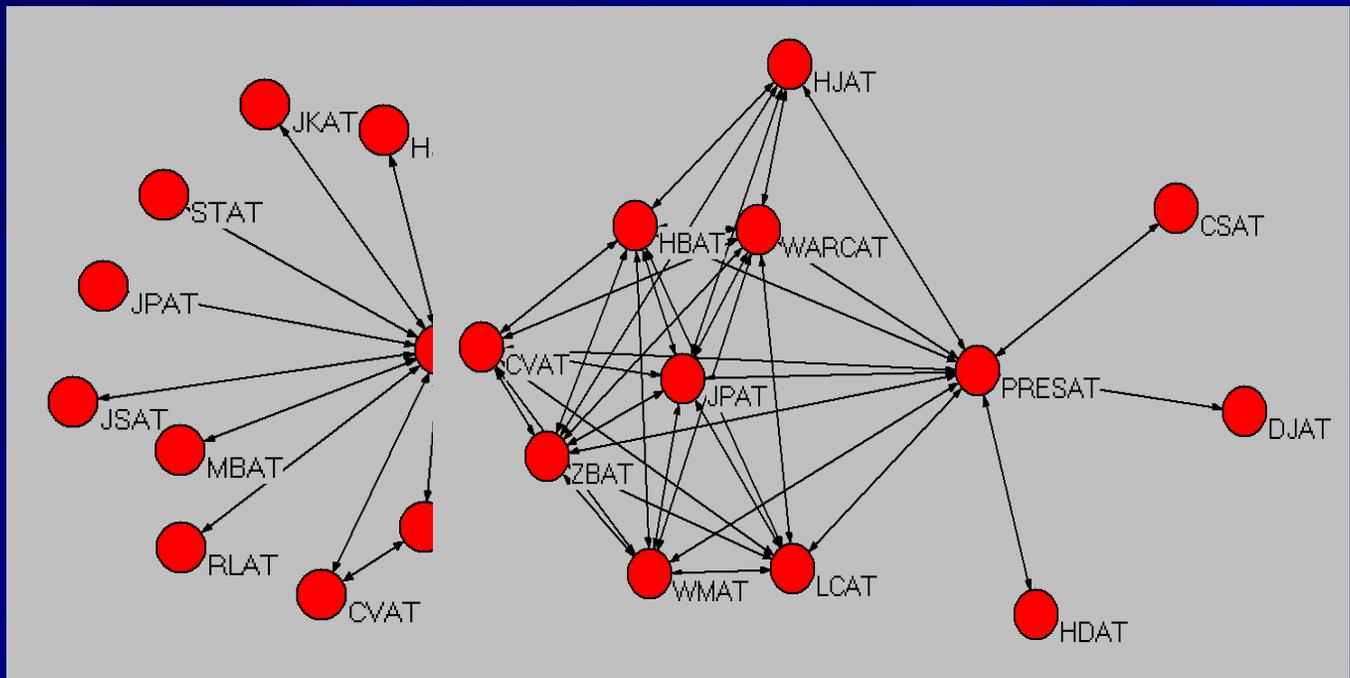
Year 1   Year 4

White House Diary Data, Carter Administration
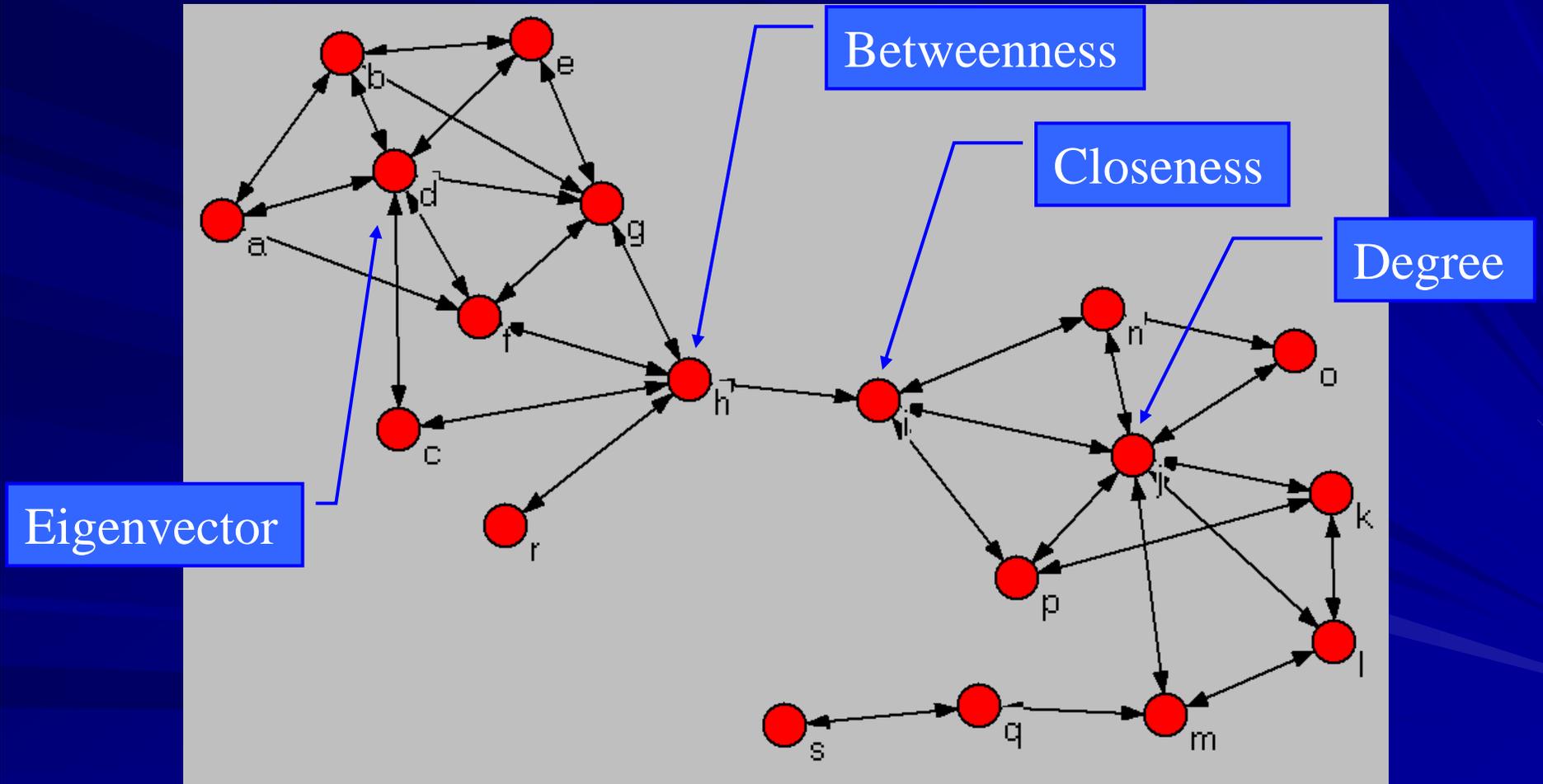
Information flow in a virtual group
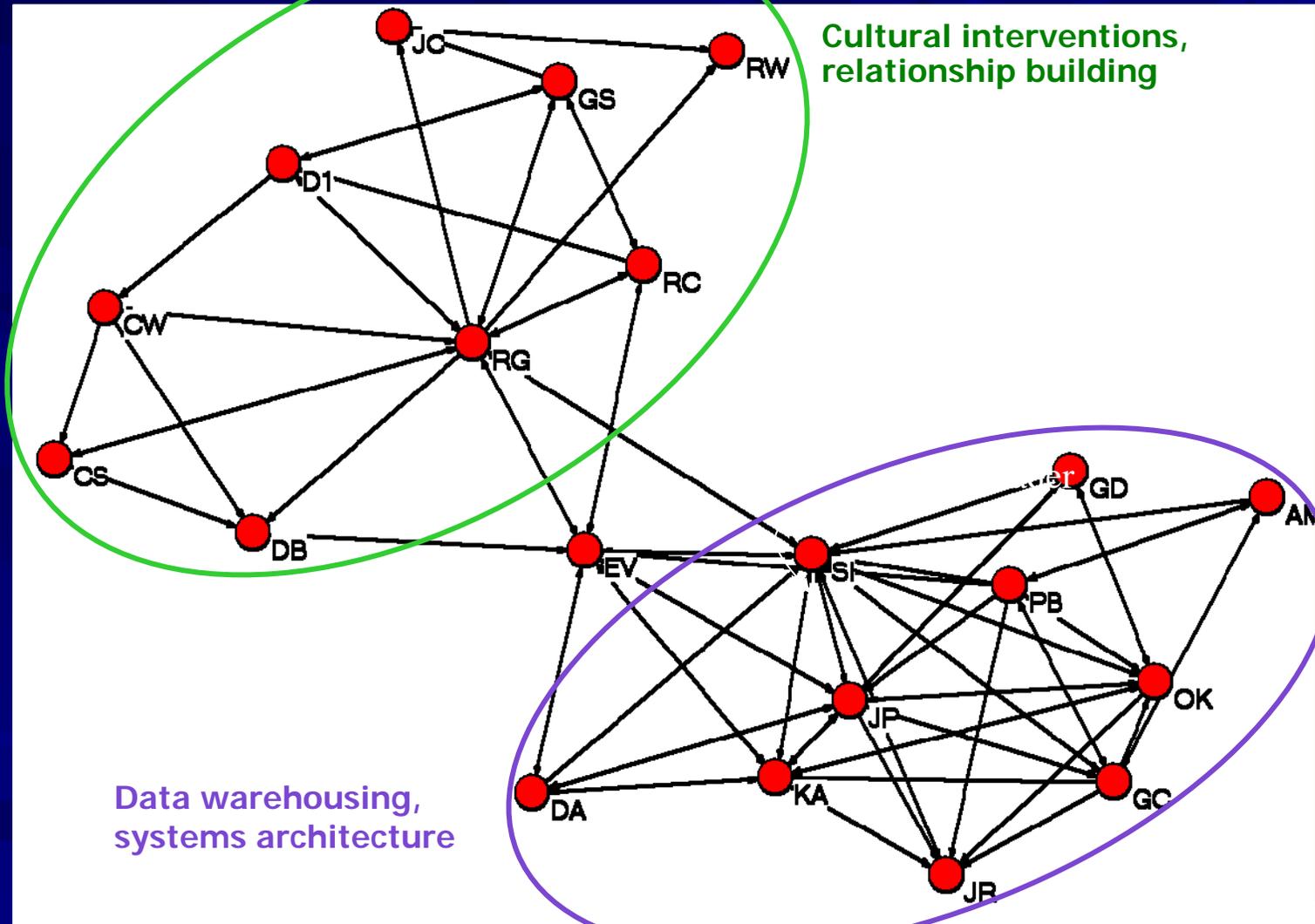
Cultural interventions, relationship building

Data warehousing, systems architecture

Cross, Parker, & Borgatti, 2002. Making Invisible Work Visible. *California Management Review*. 44(2): 25-46

Changes Made

- **Cross-staffed new internal projects**
  - white papers, database development
- **Established cross-selling sales goals**
  - managers accountable for selling projects with both kinds of expertise
- **New communication vehicles**
  - project tracking db; weekly email update
- **Personnel changes**

9 Months Later
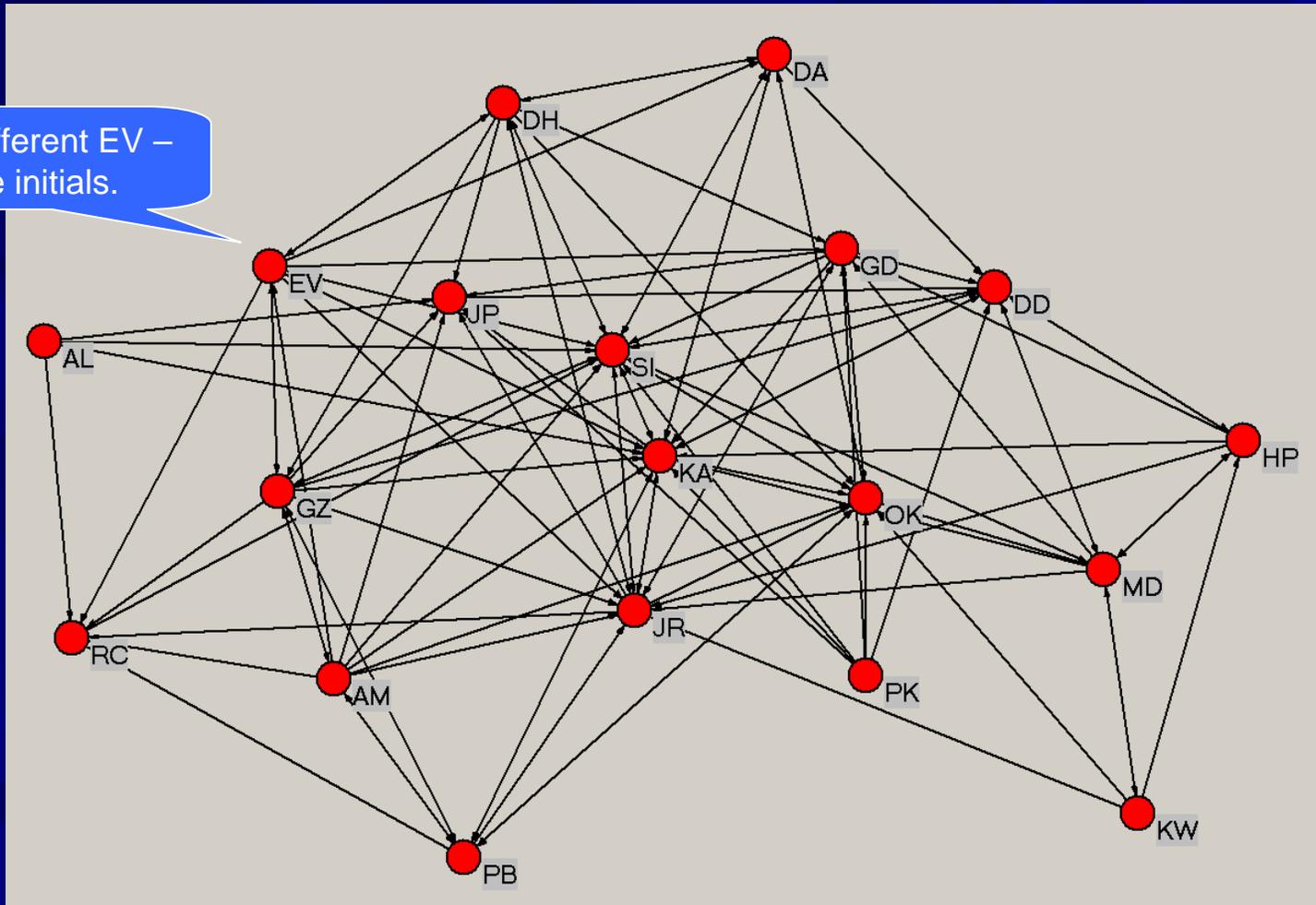
Cross, Parker, & Borgatti, 2002. Making Invisible Work Visible. *California Management Review*. 44(2): 25-46

Substantive Layer

- Antecedents of network variables
- Consequences of network variables
- Relations with other schools of thought

Causality and Network Research

- Mathematicians, methodologists, network priesthood
- How density relates to distance

- Most common area of research
- Appropriate for young field

Antecedents → **Network variables** → **Consequences**

- Rare in sociology, more common in psych, physics
- Developing in management
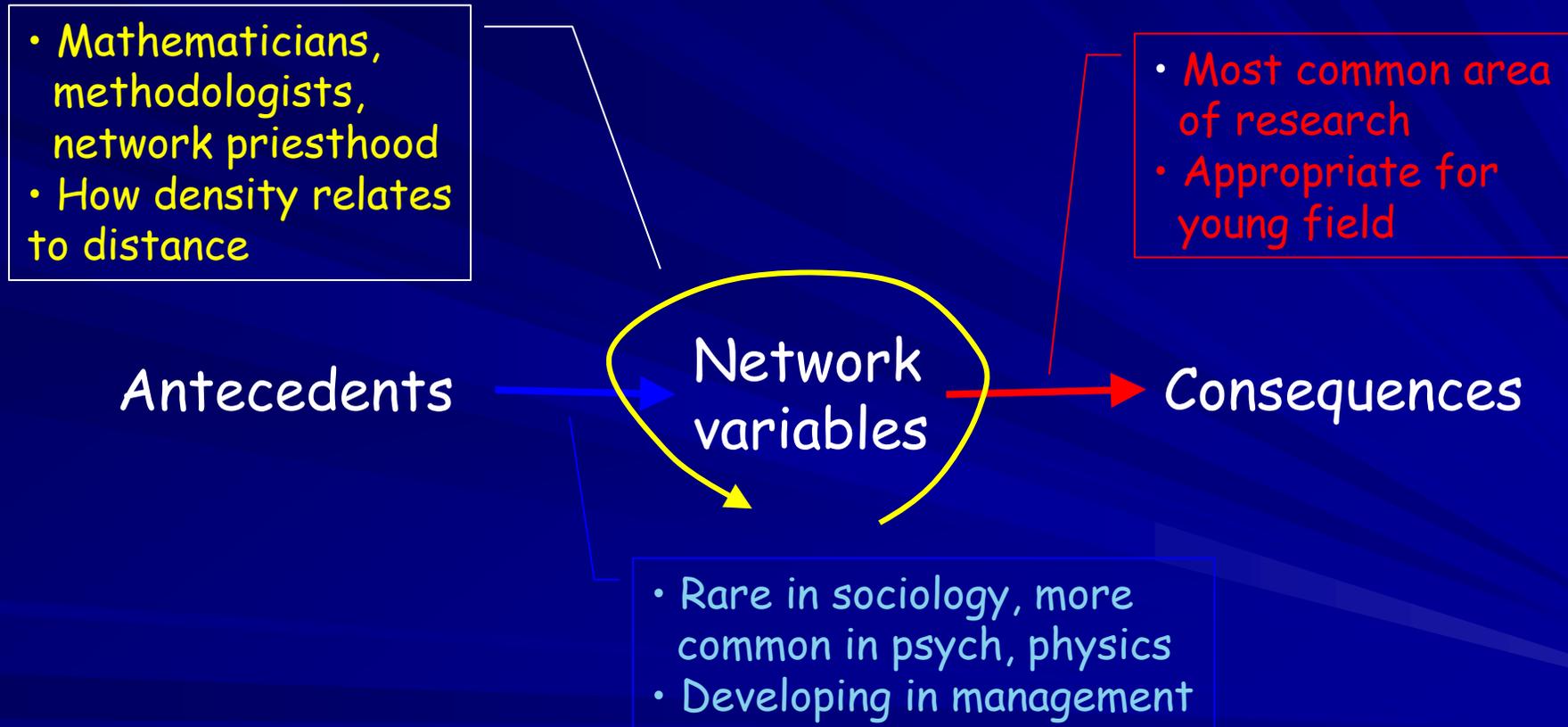
Types of hypotheses involving network variables

■ Dyad (relationship) level
  – Likelihood of office friendships increases as distance between offices decreases
  – Marriage ties between families in Renaissance Florence facilitate business ties between the same families
■ Node (actor) level
  – centrality in interaction network leads better immune system
  – Self-monitoring personality leads to higher betweenness centrality
■ Network (group) level
  – groups with c/p structure in affective network perform better
  – Compared to advice relations, affective relations will contain more transitive triples
■ Mixed dyad-node (autocorrelation)
  – Members of org units interact more members of same units (homophily)
  – Interaction leads to similarity in attitudes (influence)

Antecedents of Network Variables

- **Dyad level – who has ties with whom?**
  - Homophily
    - Propinquity
    - Common affiliation
    - Socially significant attributes
  - Triadic balance theory
    - A—B and A—C tends to lead to B—C
    - Strength of tie
  - Multiplexity
    - Cross-sectional
    - Longitudinal
- **Node characteristics**
  - Personality → centrality
- **Network (group) characteristics**
  - Small world networks (clumpy networks with short distances)
  - Scale-free networks (skewed degree distributions)
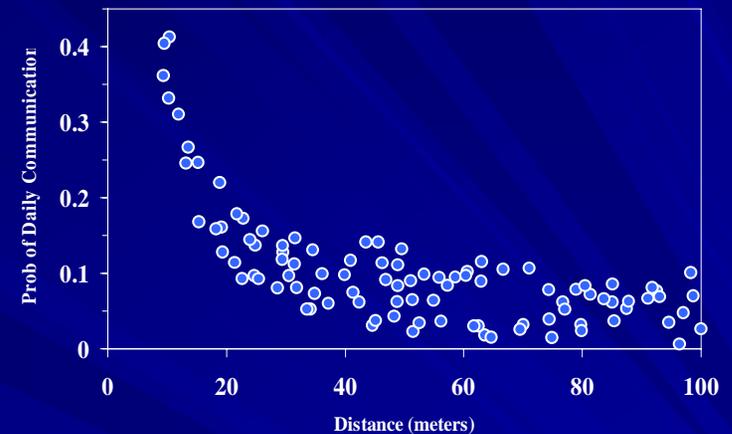
	Male	Female
Male	1245	748
Female	970	1515

Consequences of Network Variables

Means \ Ends	Explaining Variance in Performance (social capital)	Explaining Social Homogeneity (adoption)
Connectionist mechanisms (flows thru ties)	Success comes from obtaining resources <u>through</u> social ties; It's **who** you know	People have same behavior because they directly **influence** each other & transmit ideas, beliefs, etc.
Structuralist mechanisms (emergent properties of topology**)**	Network positions /shapes provide opportunities for exploitation; It's **how** you know others	People have same behavior because their network positions are similar (and affect them similarly); same **social environment**
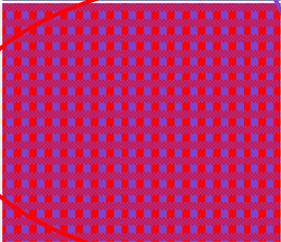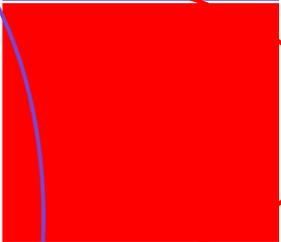
Borgatti, S.P. and Foster, P. 2003. The network paradigm in organizational research: A review and typology. *Journal of Management*. 29(6): 991-1013

Critical Assessment

Have we accomplished anything?

Where is the field going?

Changes in the Field

■ **25 years ago …**

– Descriptive, methodological

– Small datasets (< 100 nodes)

– Structuralist cast

– Focus on the consequences of network characteristics

■ Network is fixed

■ Cross-sectional data

– Focus on the pattern of ties

– Deterministic & analytical models

– Inter-network comparisons

■ **Now …**

– Theory testing in soc sci

– Large datasets 00s – 000s

– Increasing attention to agency

– Increasing attention to causes of network variables

■ Network change

■ Longitudinal data

– Increasing interest in what flows through networks

– Increasing interest in stochastic models & simulations

– Comparison with theoretical baselines

Theoretical Perspectives