

# INTRODUCTION TO SOCIAL NETWORK ANALYSIS

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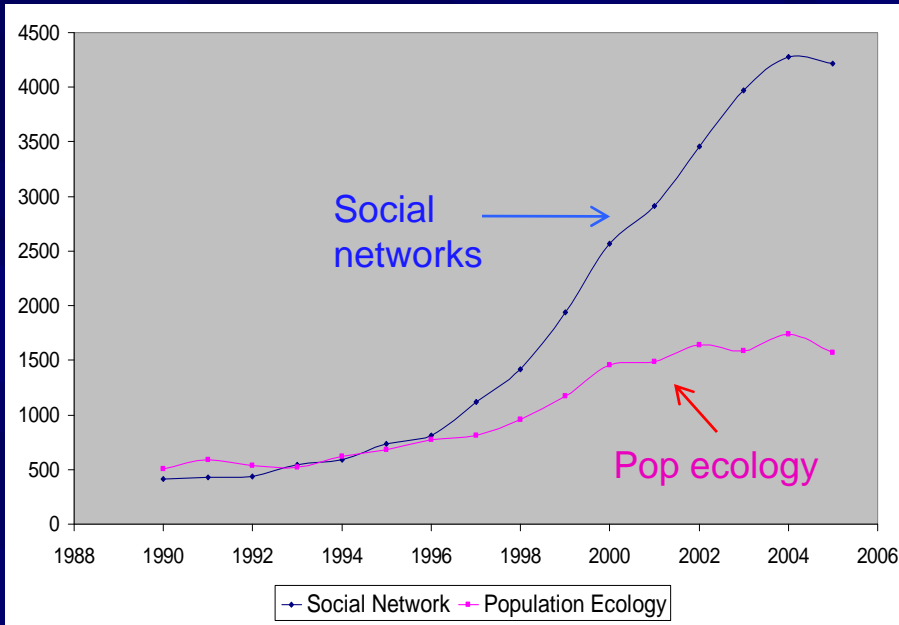
# In this presentation ...

Painting by Idahlia Stanley

- SNA as a discipline
- What is distinct
- Overview of theoretical concepts
- A few methodological issues

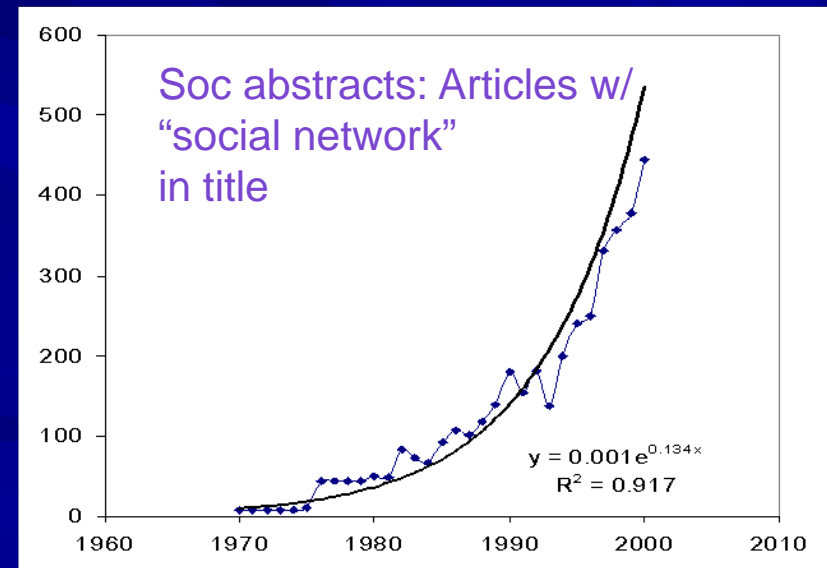


# Explosive Growth



- Google page rank
- Social networking software
- Management consulting
- Network organizations
- Anti-terrorism
- Epidemiology

- Embeddedness, social capital, SRT, collab theory
- TCE, RD, Institutional theory, transactional knowledge, etc



# 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
  - Modern field of SN is established (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





# Formal Organization

## ■ Professional Assoc. (since '78)

- Int'l Network for Social Network Analysis -  
[www.insna.org](http://www.insna.org)
- Incorporated 1993

## ■ No dept. of Social Network Analysis

- But a few centers ...

## ■ Centers

- LINKS (U of Kentucky)
- Network Roundtable (U of Virginia)
- CASOS (Carnegie Mellon)
- Networked Governance (Harvard)
- Watson Research Center (IBM )
- NICO (Northwestern)
- ISNAE
- IMBS (UC-Irvine)
- Coalition Theory Network (European consortium)
- CCNR (Notre Dame, Physics)
- Nuffield Network Researchers (Oxford)
- Bader Lab (U of Toronto, Biology)
- CSSS (U of Washington, Statistics)

# Conferences & Workshops

## ■ Sunbelt annual conference (since '79)

- 2001: Budapest, HUNGARY
- 2002: New Orleans, USA
- 2003: Cancun, MEXICO
- 2004: Portorôš, SLOVENIA
- 2005: Los Angeles, USA
- 2006: Vancouver, CANADA
- 2007: Corfu, GREECE
- 2008: St Pete, Florida, USA
- 2009: San Diego, USA
- 2009: Trento, ITALY

## ■ Regular Training Workshops

- Sunbelt social networks conference
  - 1-day workshops
- Academy of Management
- University of Essex, UK
  - 2-week
- CARMA
  - 1-week
- ICPSR-Michigan
- LINKS center
  - Coming soon!

# Resources

## ■ 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
- SIENA
- STRUCTURE;  
GRADAP; KRACKPLOT

## ■ Listservs & Groups

- SOcNET listserv (1993)
- REDES listserv
- UCINET user's group

# Online Resources

- [www.analytictech.com/mgt780](http://www.analytictech.com/mgt780)
- <http://linkscenter.org>
- [www.insna.org](http://www.insna.org)
- [www.analytictech.com/networks](http://www.analytictech.com/networks)





# BASIC IDEA

# Mainstream Social Science

- Individual outcomes as a function of individual attributes
  - Predict career success as a function of a person's training, experience, skills, looks, etc .
- Analysis consists of correlating columns
  - Typically identify one column as the thing to be explained
  - We explain one attribute as a function of the others

Variables  
(attributes)

	Age	Sex	Education	Income
1001				
1002				
1003				
1004				
1005				
...				

Cases  
(entities)

# Attributes to Relations

- Shift from *attributes of the individual* as sole explanation to their *relationships and interactions with others* as also explanatory
- The case of entrepreneurial success
  - Success a function of entrepreneur's talents and resources
  - But the person themselves don't have to have all of these talents themselves, they just need to know someone who does
  - Its who you know, and what qualities those people have
  - And it's about the nature of your relationship – can you draw on their resources?
  - Social resource theory (Nan Lin)

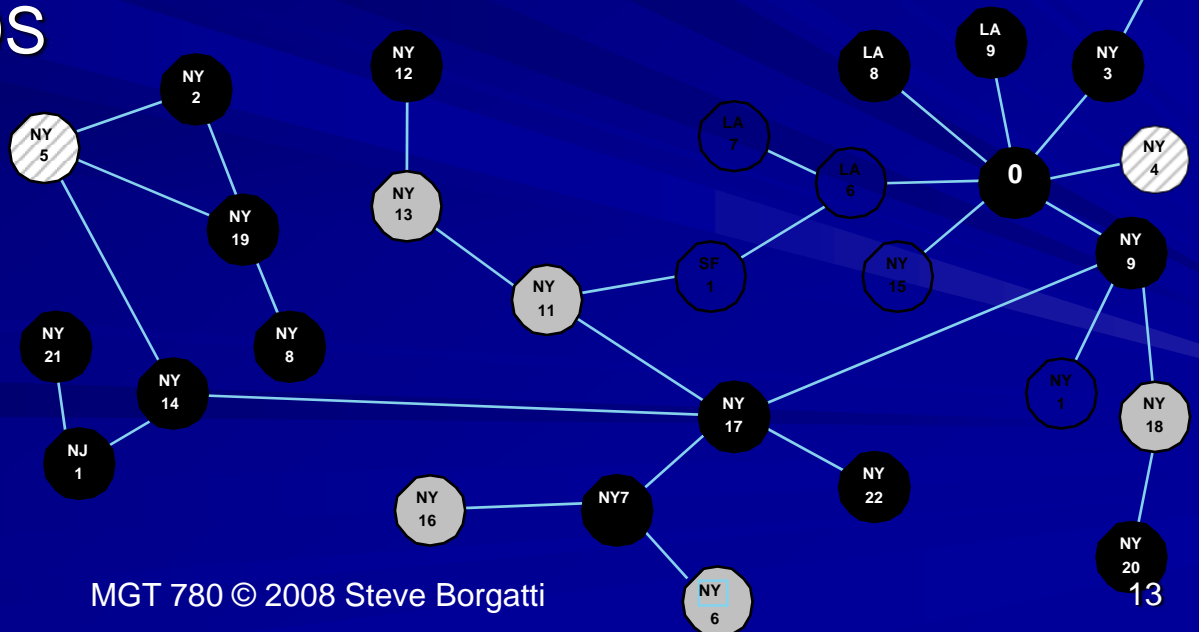
# Attributes to Relations

- Shift from *attributes of the individual* as sole explanation to their *relationships and interactions with others* as also explanatory
- The case of entrepreneurial success
- The case of the iPhone
  - Who adopts a gadget such as an iphone?
  - Mechanism of social influence



# Attributes to Relations

- Shift from *attributes of the individual* as sole explanation to their *relationships and interactions with others* as also explanatory
- The case of entrepreneurial success
- The case of the iPhone
- The case of AIDS
  - Homosexuality or contagion?



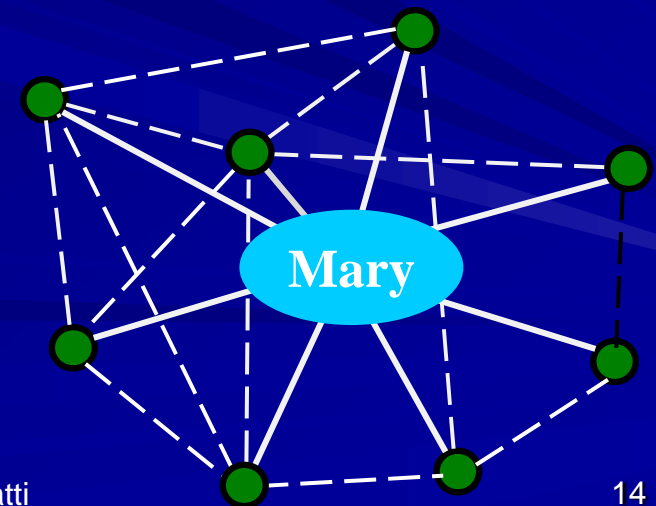
# What's entailed in this shift?

## ■ Theory

- Looking to the person's environment for explanation
  - Seeing that environment as individuals
  - Focusing on the nature of the ties with those individuals
- Interpersonal processes as influence, contagion

## ■ Methodology

- Collecting data on relationships as well as individuals
- New unit of observation: the dyad



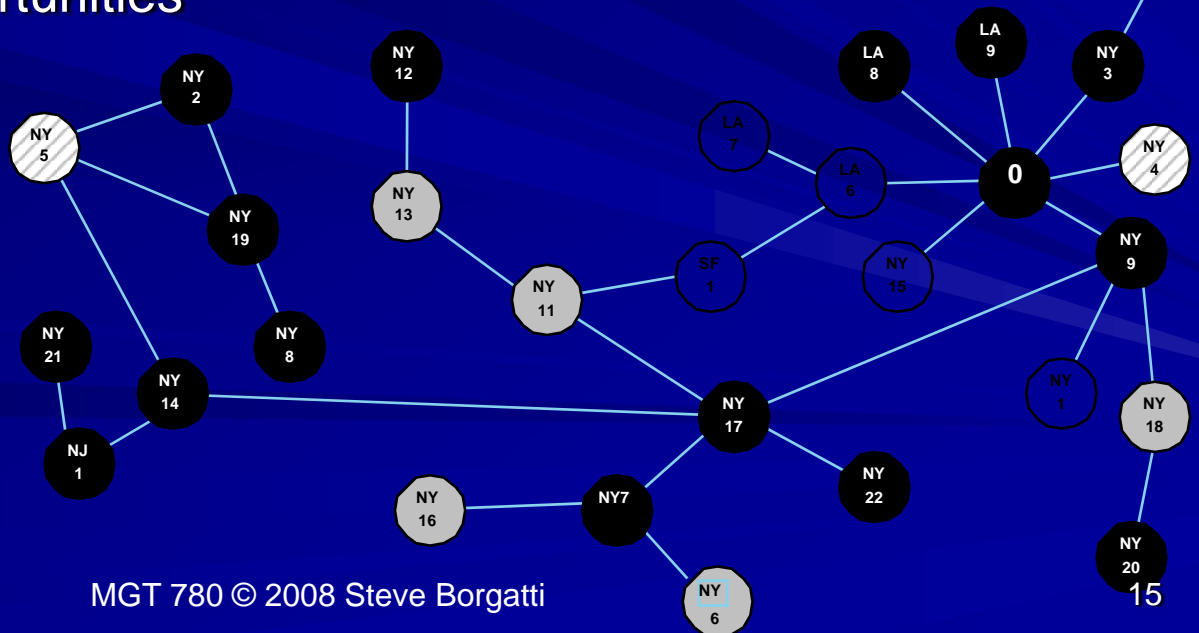
# What else is entailed?

- Dyads link up to form networks

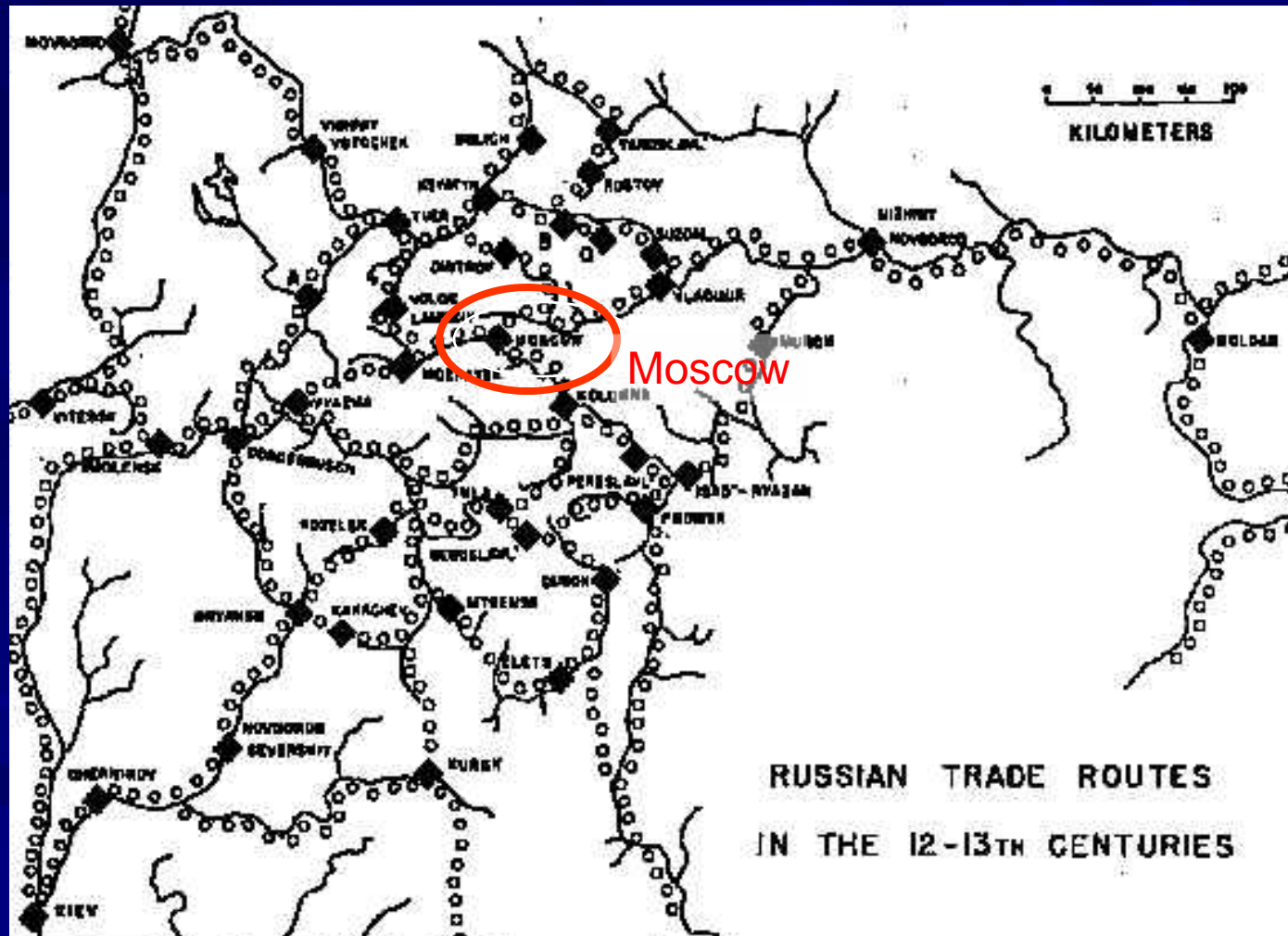
- How strangers affect your outcomes: Propagations and flows through network paths

- Position in the network matters

- Centrality
- Risks and opportunities

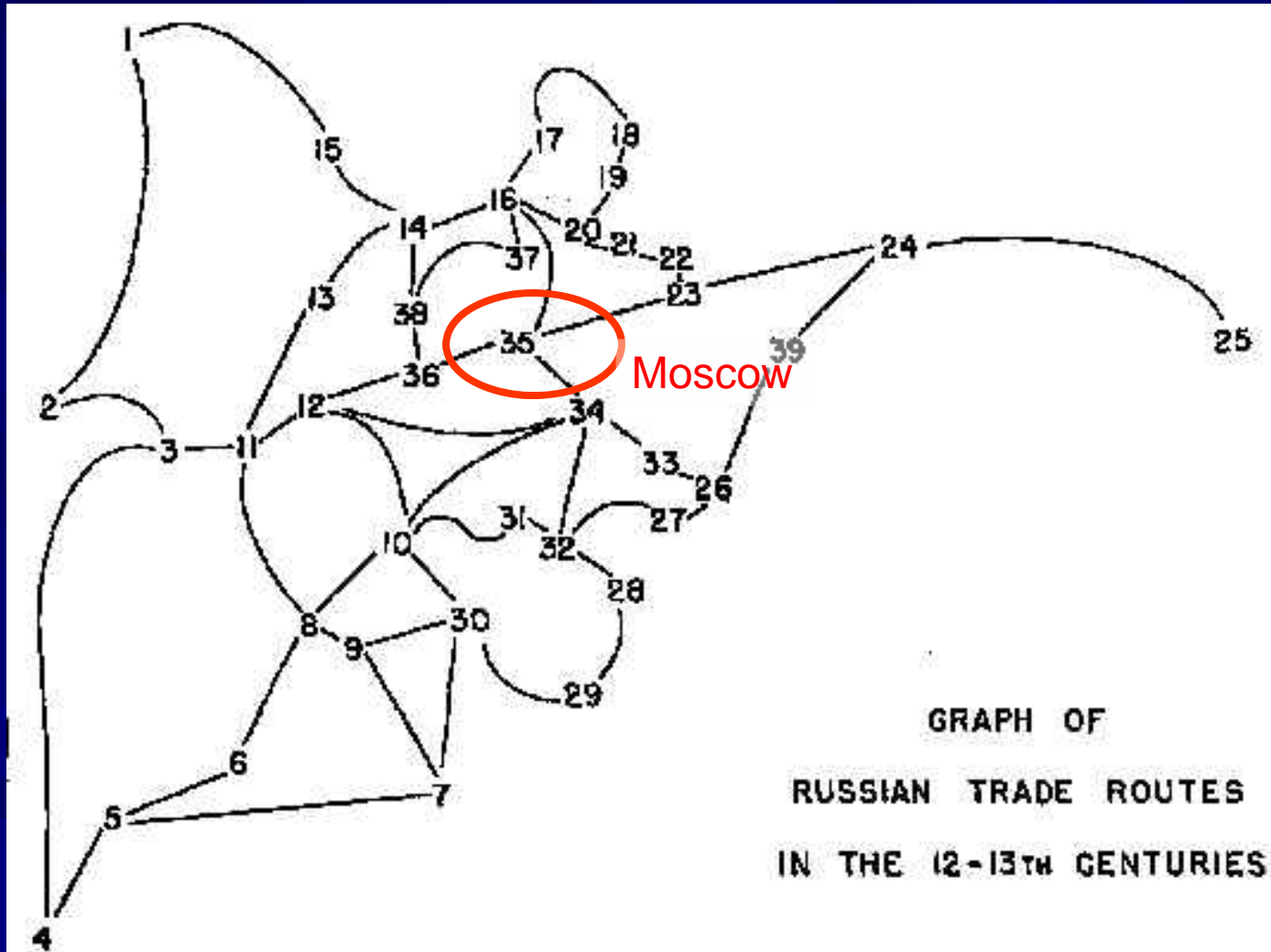


# Case Study: Pitts' analysis of Moscow's emergence to pre-eminence



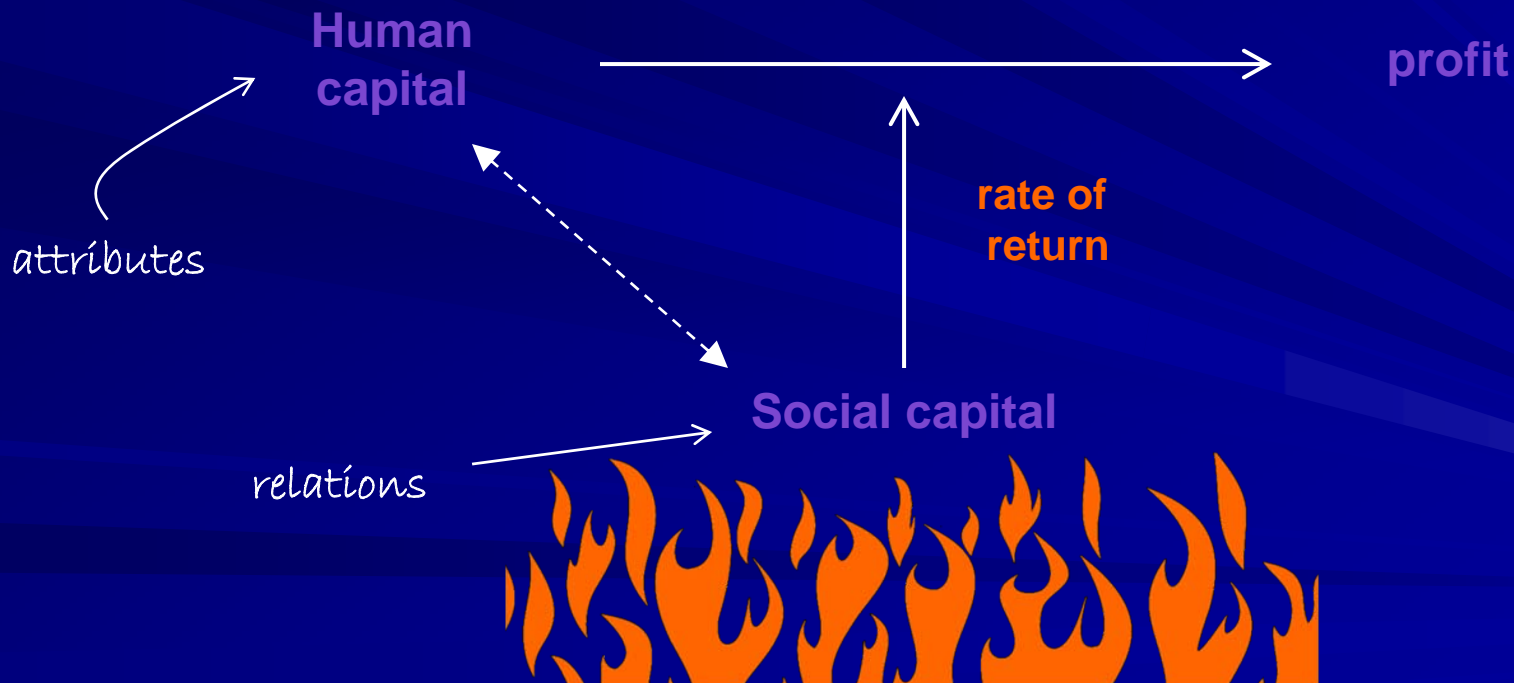


# Position in the River Network



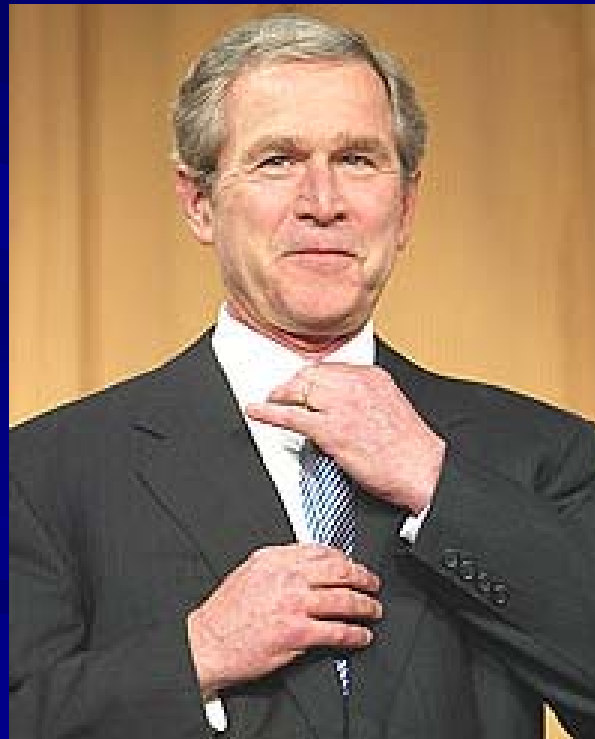
# Rate of return on human capital

- Burt (1992): A person's connections determine the rate of return on human capital



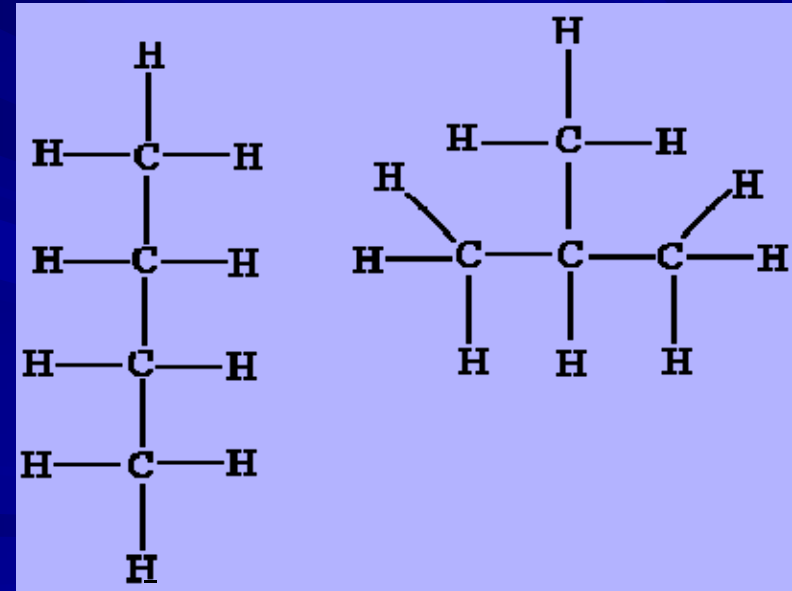
# Human Capital and Social Capital

- How far can you get on human capital alone?
- Betting on social capital



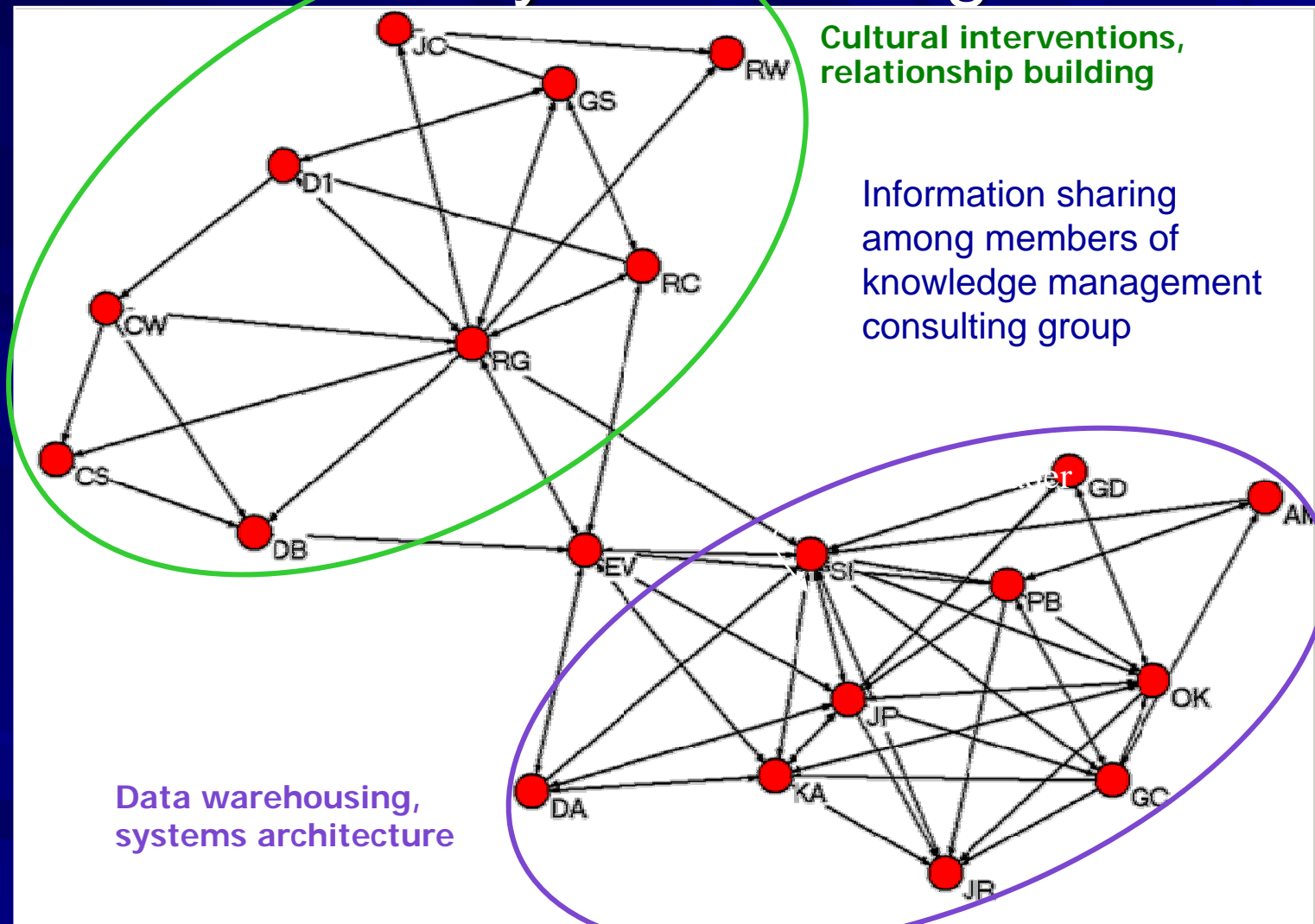
# What else is entailed?

- Dyads link up to form networks
  - How strangers affect your outcomes: Propagations and flows through network paths
- Position in the network matters
  - Centrality
  - Risks and opportunities
- Structure matters
  - It's not just about resources, it is how they are configured
  - “Chemistry” of a basketball team





# Case Study: Consulting Firm



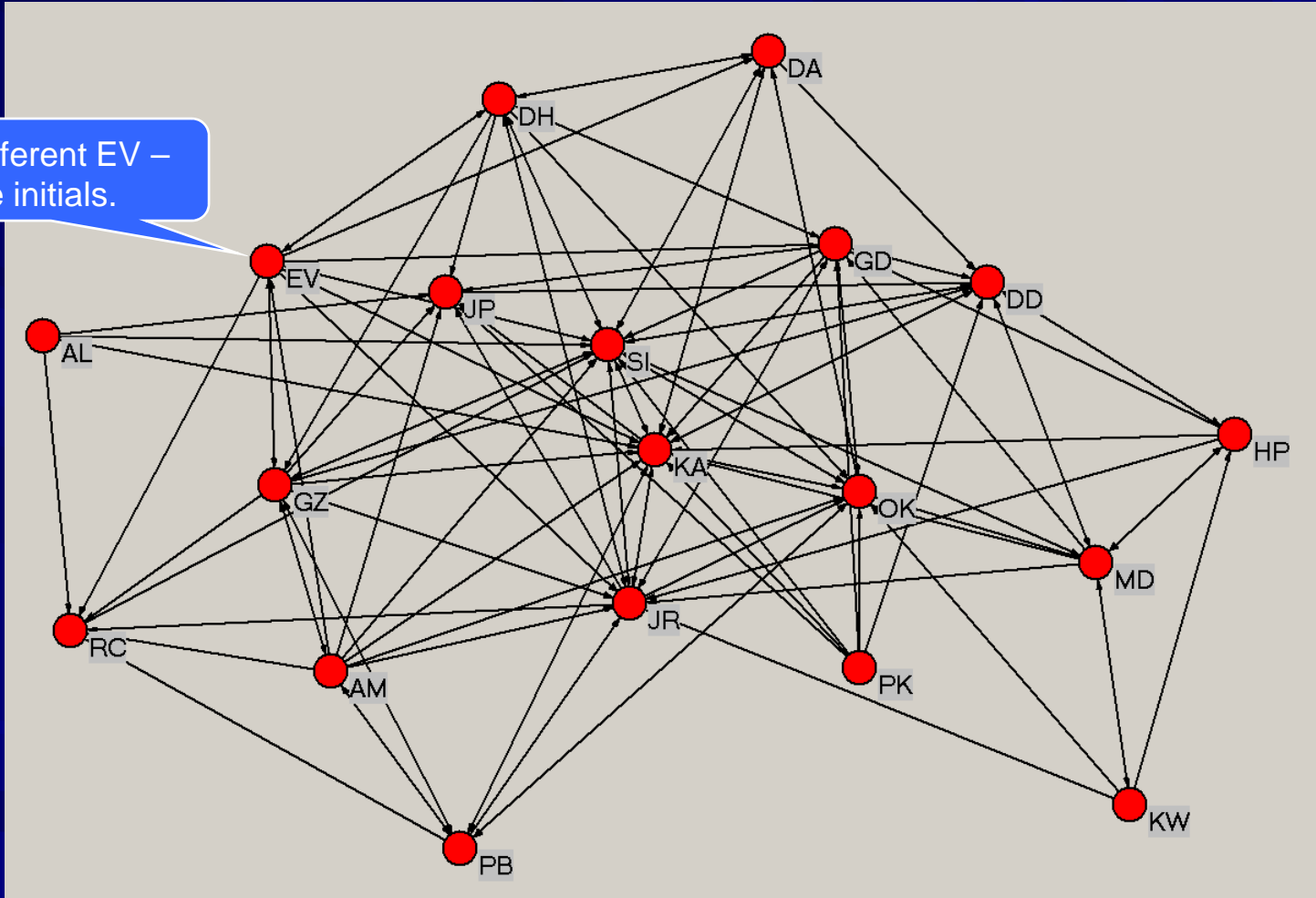
Cross, Parker, & Borgatti, 2002. Making Invisible Work Visible. *California Management Review*. 44(2): 25-46

# 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

Note: Different EV – same initials.

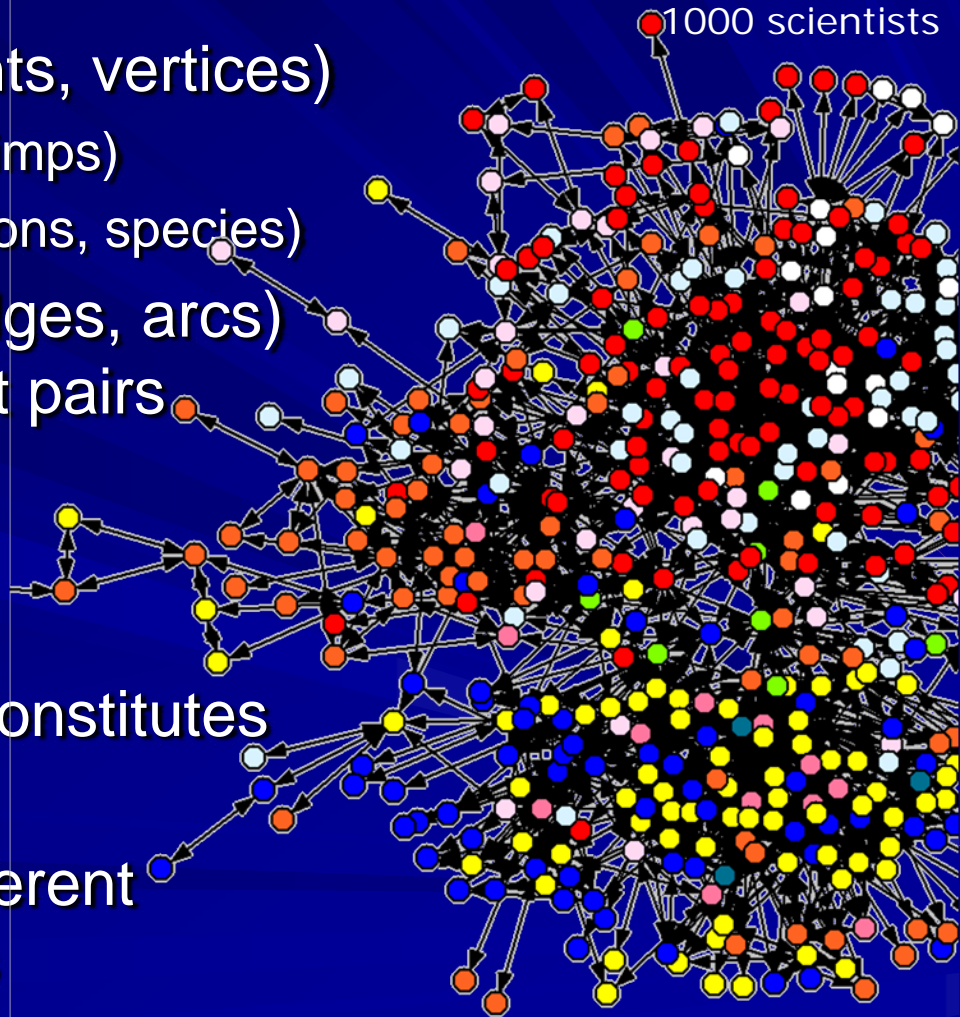


Cross, Parker, & Borgatti, 2002. Making Invisible Work Visible. *California Management Review*. 44(2): 25-46

# **BASIC CONCEPTS**

# 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) of a given type that connect pairs of actors in the set
  - Directed or undirected
  - Valued or presence/absence
- Set of ties of a given type constitutes a social relation
- Different relations have different structures & consequences



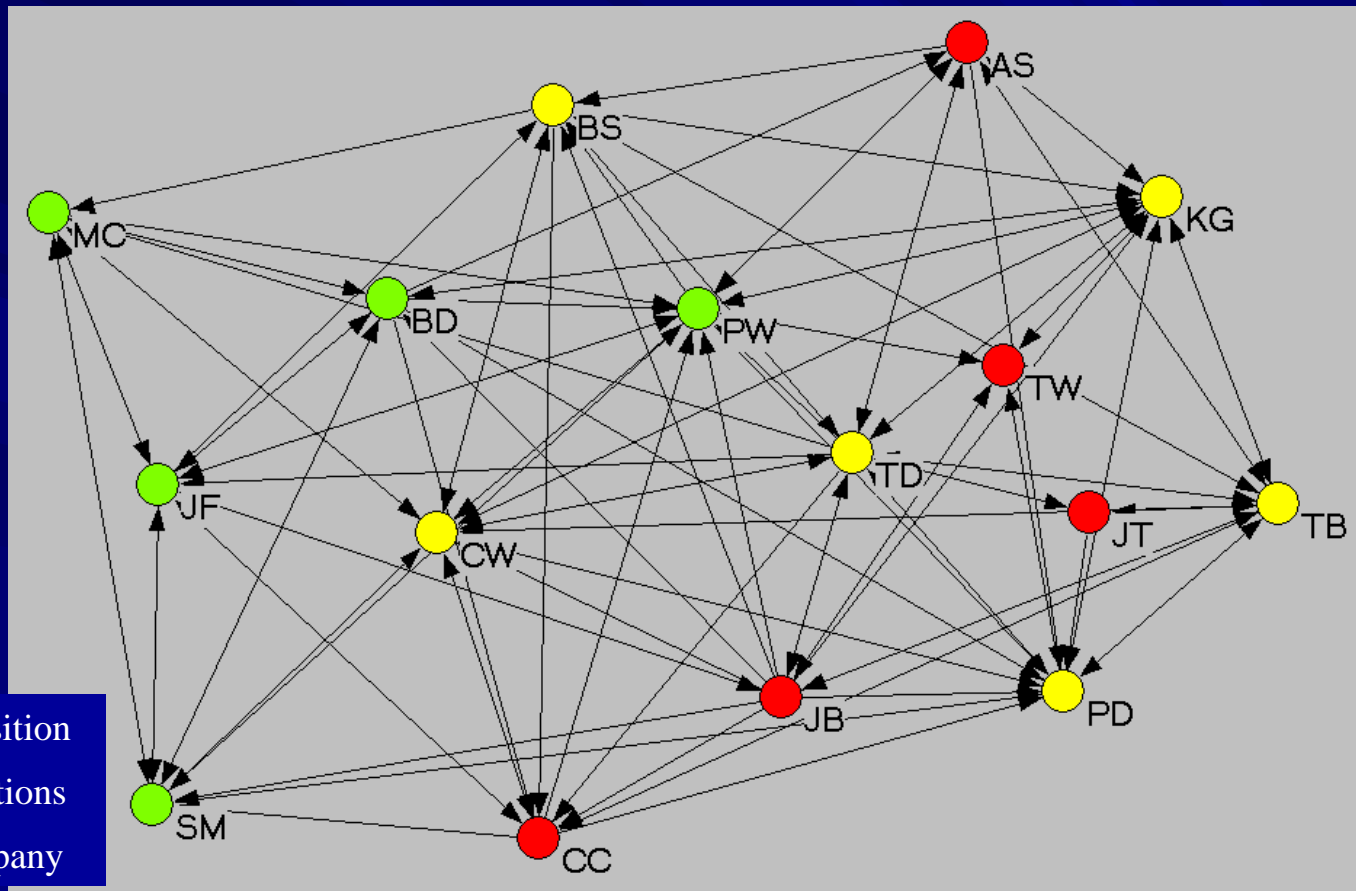


# Case Study: Simple Answers

Who you ask for answers to straightforward questions.

HR Dept  
of Large  
Health Care  
Organization

- Recent acquisition
- Older acquisitions
- Original company

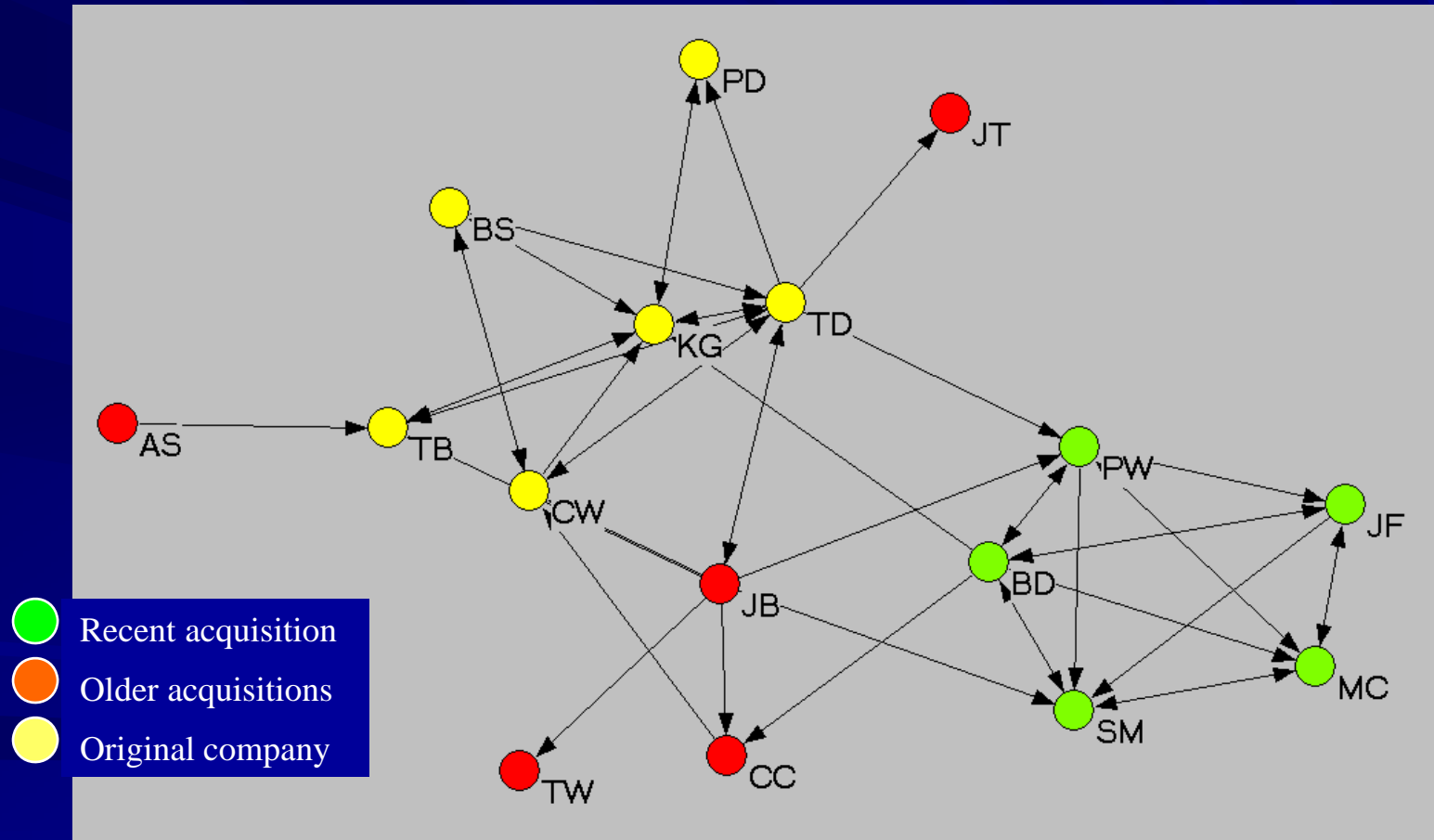


Cross, R., Borgatti, S.P., & Parker, A. 2001. Beyond Answers: Dimensions of the Advice

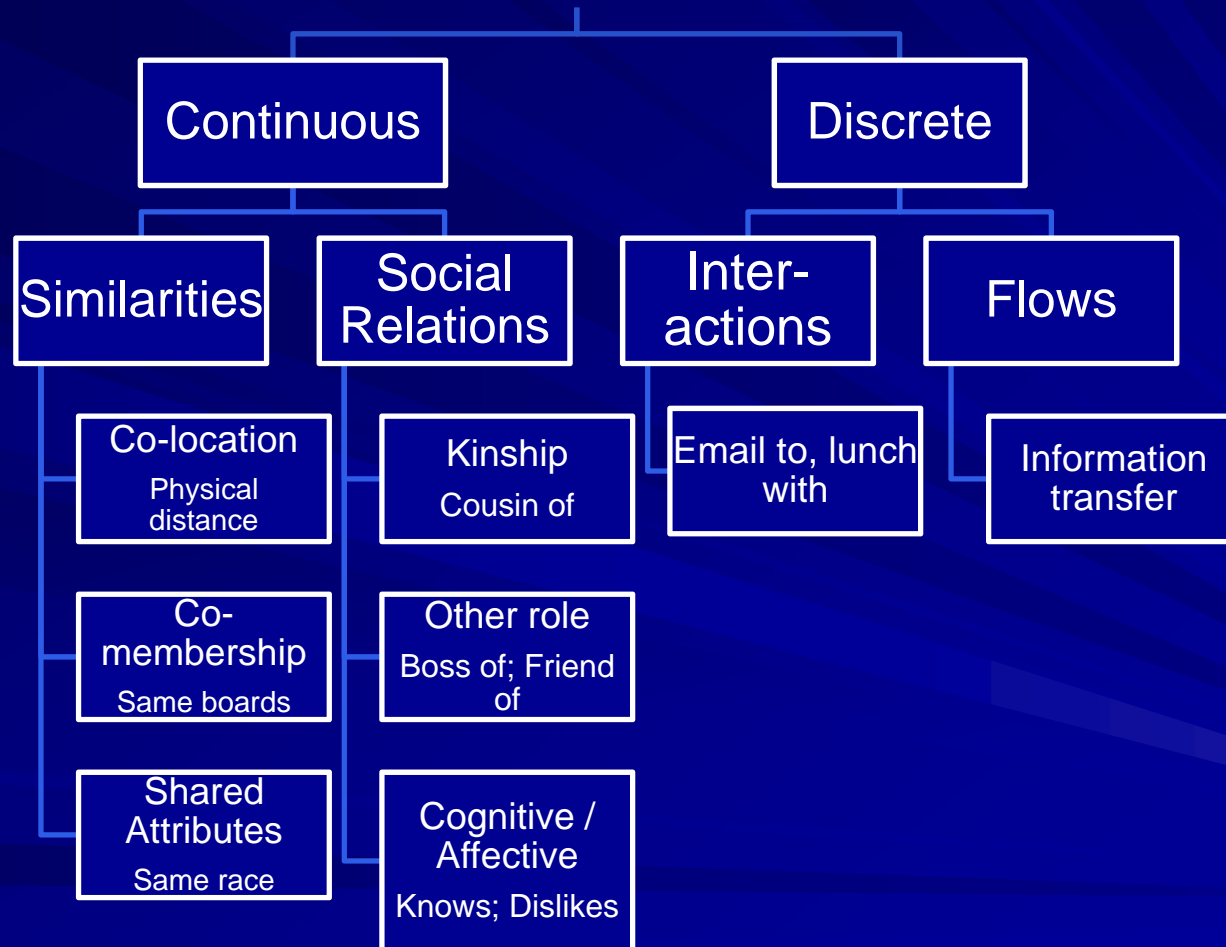
Network. *Social Networks* 23(3): 215-235

# Problem Reformulation

Who you see to help you think through issues



# Types of Ties among Persons



# 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

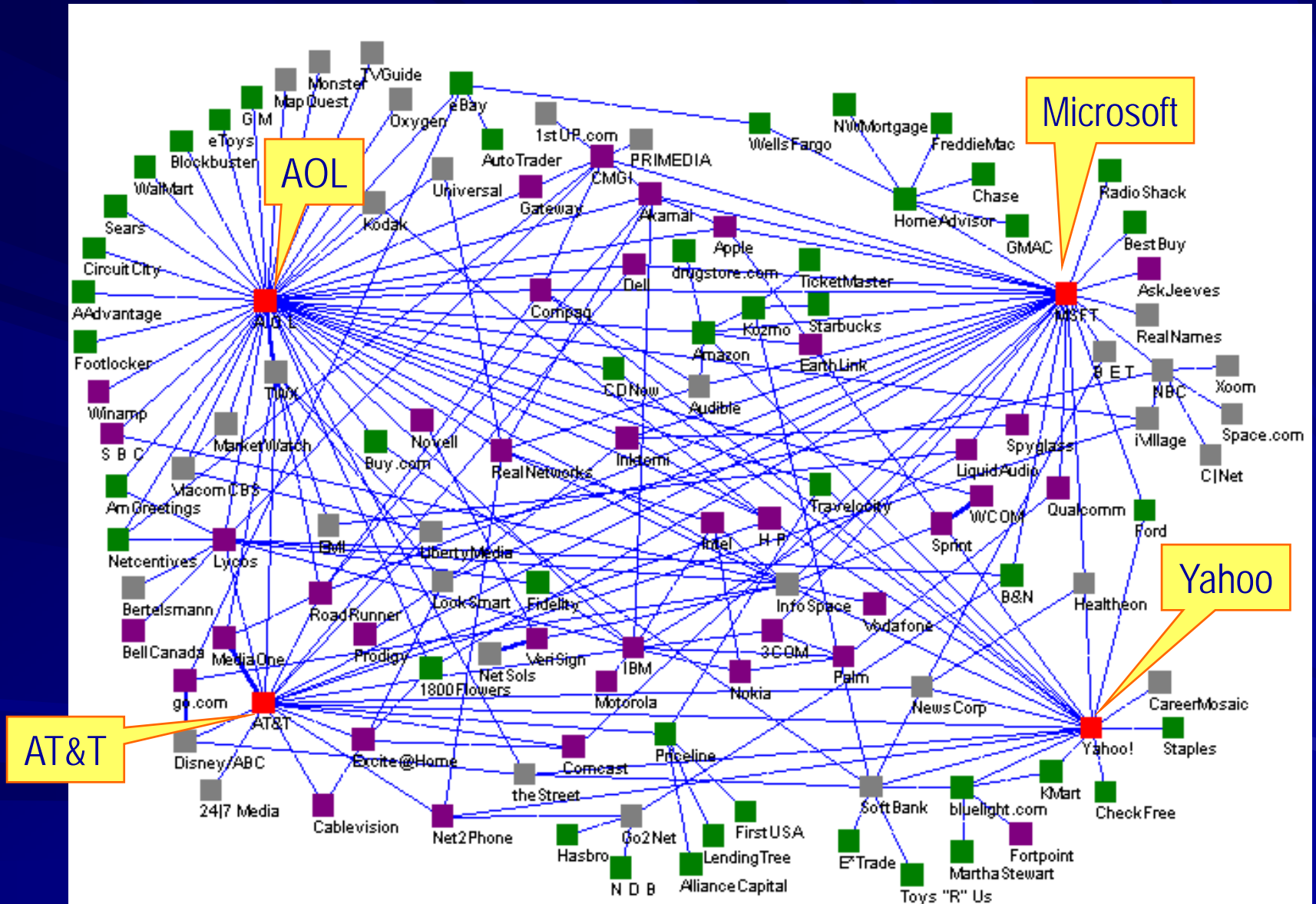
# Types of Inter-Organizational Ties

Cross-classified by type of tie and type of node

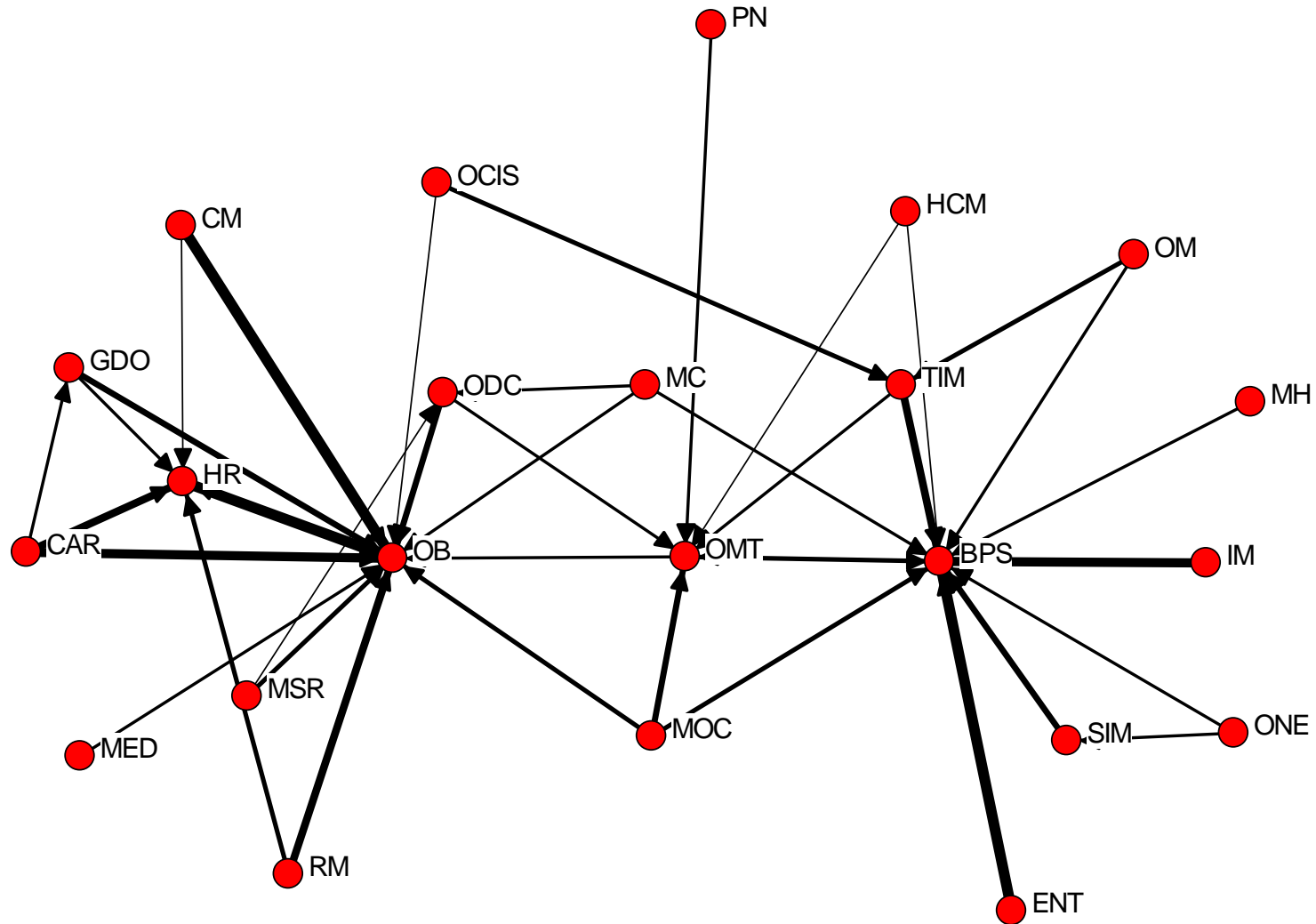
Type of Tie	Firms as Entities	Via Individuals
<b>Similarities</b>	Joint membership in trade association; Co-located in Silicon valley	Interlocking directorates; CEO of A is next-door neighbor of CEO of B
<b>Relations</b>	Joint ventures; Alliances; Distribution agreements; Own shares in; Regards as competitor	Chief Scientist of A is friends with Chief Scientist of B
<b>Interactions</b>	Sells product to; Makes competitive move in response to	Employees of A go bowling with employees of B
<b>Flows</b>	Technology transfers; Cash infusions such as stock offerings	Emp of A leaks information to emp of B



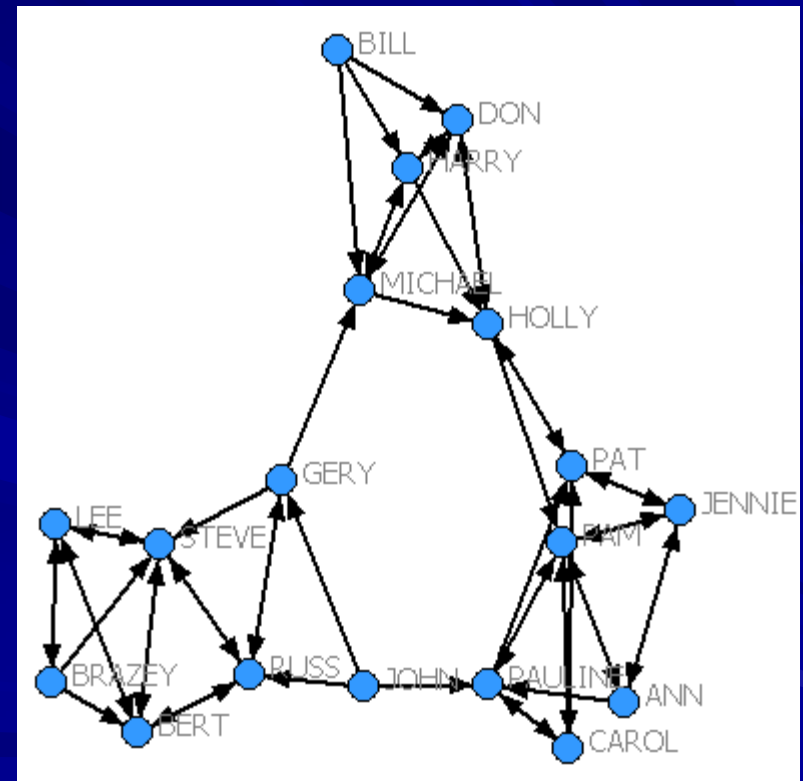
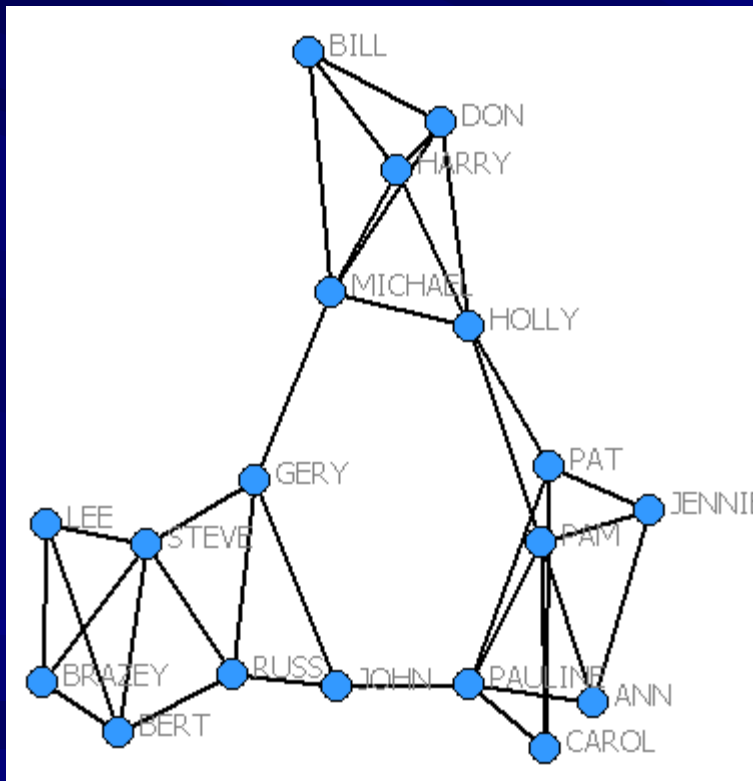
# Internet Alliances



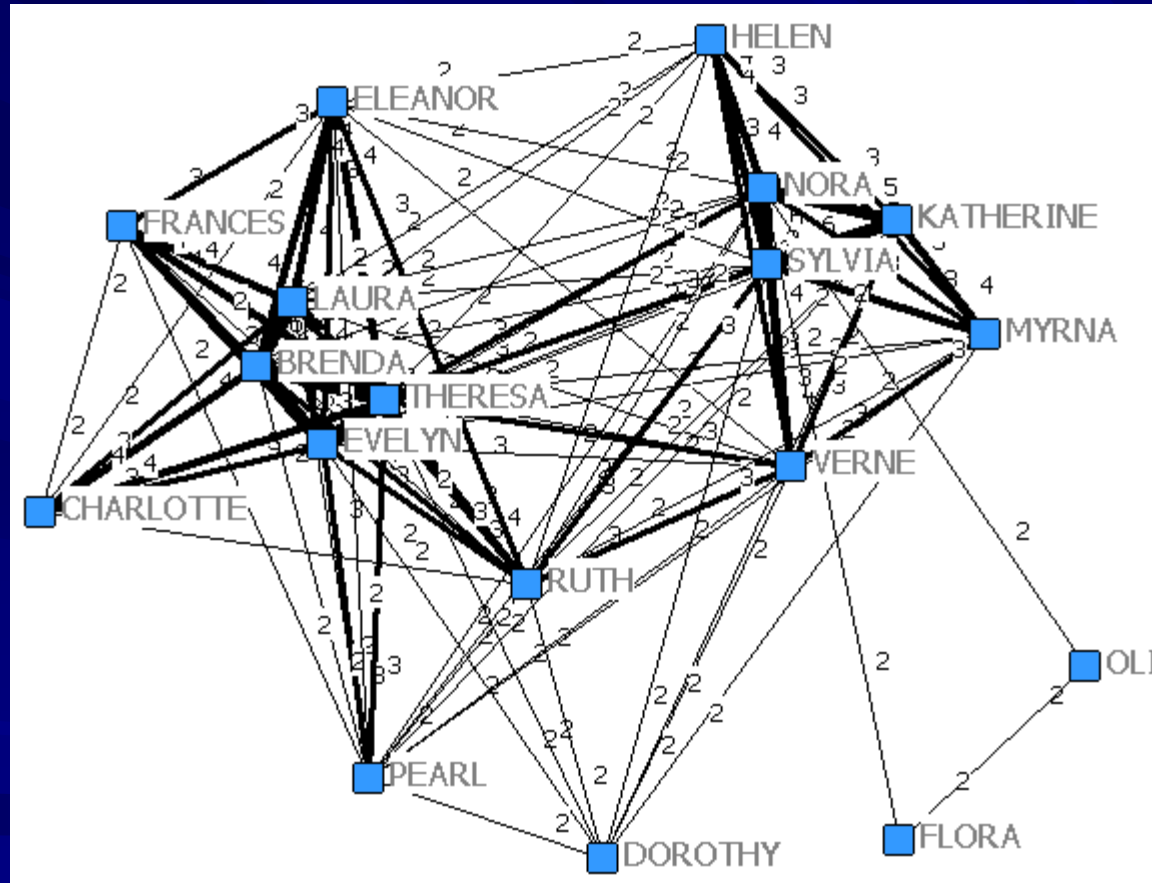
# Academy of Management Division Co-Membership > 27%



# Symmetric versus non-symmetric relations

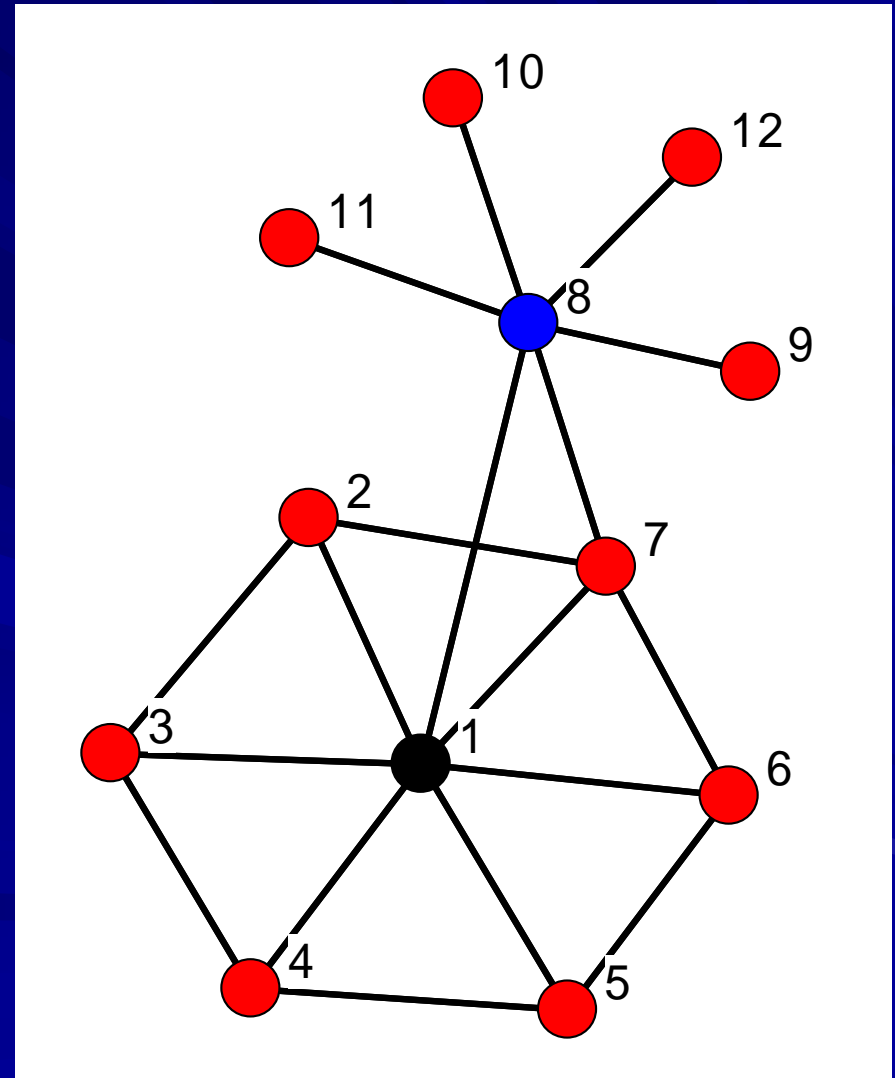


# Valued Ties



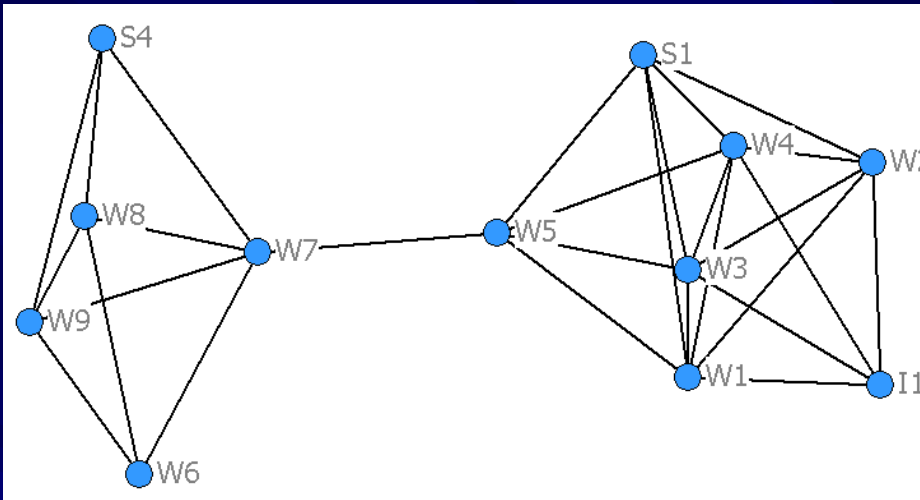
# Walks, Trails, Paths

- Path: can't repeat node
  - 1-2-3-4-5-6-7-8
  - Not 7-1-2-3-7-4
- Trail: can't repeat line
  - 1-2-3-1-7-8
  - Not 7-1-2-7-1-4
- Walk: unrestricted
  - 1-2-3-1-2-7-1-7-1





# Graphical versus adjacency matrix representations



Who is friends  
with whom

	I1	I3	W1	W2	W3	W4	W5	W6	W7	W8	W9	S1	S2	S4	Sum	Avg
I1		0	1	1	1	1	0	0	0	0	0	0	0	0	4	0.31
I3	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
W1	1	0		1	1	1	1	0	0	0	0	1	0	0	6	0.46
W2	1	0	1		1	1	0	0	0	0	0	1	0	0	5	0.38
W3	1	0	1	1		1	1	0	0	0	0	1	0	0	6	0.46
W4	1	0	1	1	1		1	0	0	0	0	1	0	0	6	0.46
W5	0	0	1	0	1	1		0	1	0	0	1	0	0	5	0.38
W6	0	0	0	0	0	0	0		1	1	1	0	0	0	3	0.23
W7	0	0	0	0	0	0	1	1		1	1	0	0	1	5	0.38
W8	0	0	0	0	0	0	0	1	1		1	0	0	1	4	0.31
W9	0	0	0	0	0	0	0	1	1	1		0	0	1	4	0.31
S1	0	0	1	1	1	1	1	0	0	0	0		0	0	5	0.38
S2	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0.00
S4	0	0	0	0	0	0	0	0	1	1	1	0	0		3	0.23
Sum	4	0	6	5	6	6	5	3	5	4	4	5	0	3	56	
Avg	0.31	0.00	0.46	0.38	0.46	0.46	0.38	0.23	0.38	0.31	0.31	0.38	0.00	0.23		0.31

# Adjacency Matrix

	I1	I3	W1	W2	W3	W4	W5	W6	W7	W8	W9	S1	S2	S4	Sum	Avg
I1		0	1	1	1	1	0	0	0	0	0	0	0	0	4	0.31
I3	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
W1	1	0		1	1	1	1	0	0	0	0	1	0	0	6	0.46
W2	1	0	1		1	1	0	0	0	0	0	1	0	0	5	0.38
W3	1	0	1	1		1	1	0	0	0	0	1	0	0	6	0.46
W4	1	0	1	1	1		1	0	0	0	0	1	0	0	6	0.46
W5	0	0	1	0	1	1		0	1	0	0	1	0	0	5	0.38
W6	0	0	0	0	0	0	0		1	1	1	0	0	0	3	0.23
W7	0	0	0	0	0	0	1	1		1	1	0	0	1	5	0.38
W8	0	0	0	0	0	0	0	1	1		1	0	0	1	4	0.31
W9	0	0	0	0	0	0	0	1	1	1		0	0	1	4	0.31
S1	0	0	1	1	1	1	1	0	0	0	0		0	0	5	0.38
S2	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0.00
S4	0	0	0	0	0	0	0	0	1	1	1	0	0		3	0.23
Sum	4	0	6	5	6	6	5	3	5	4	4	5	0	3	56	
Avg	0.31	0.00	0.46	0.38	0.46	0.46	0.38	0.23	0.38	0.31	0.31	0.38	0.00	0.23		0.31

# Multiple 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

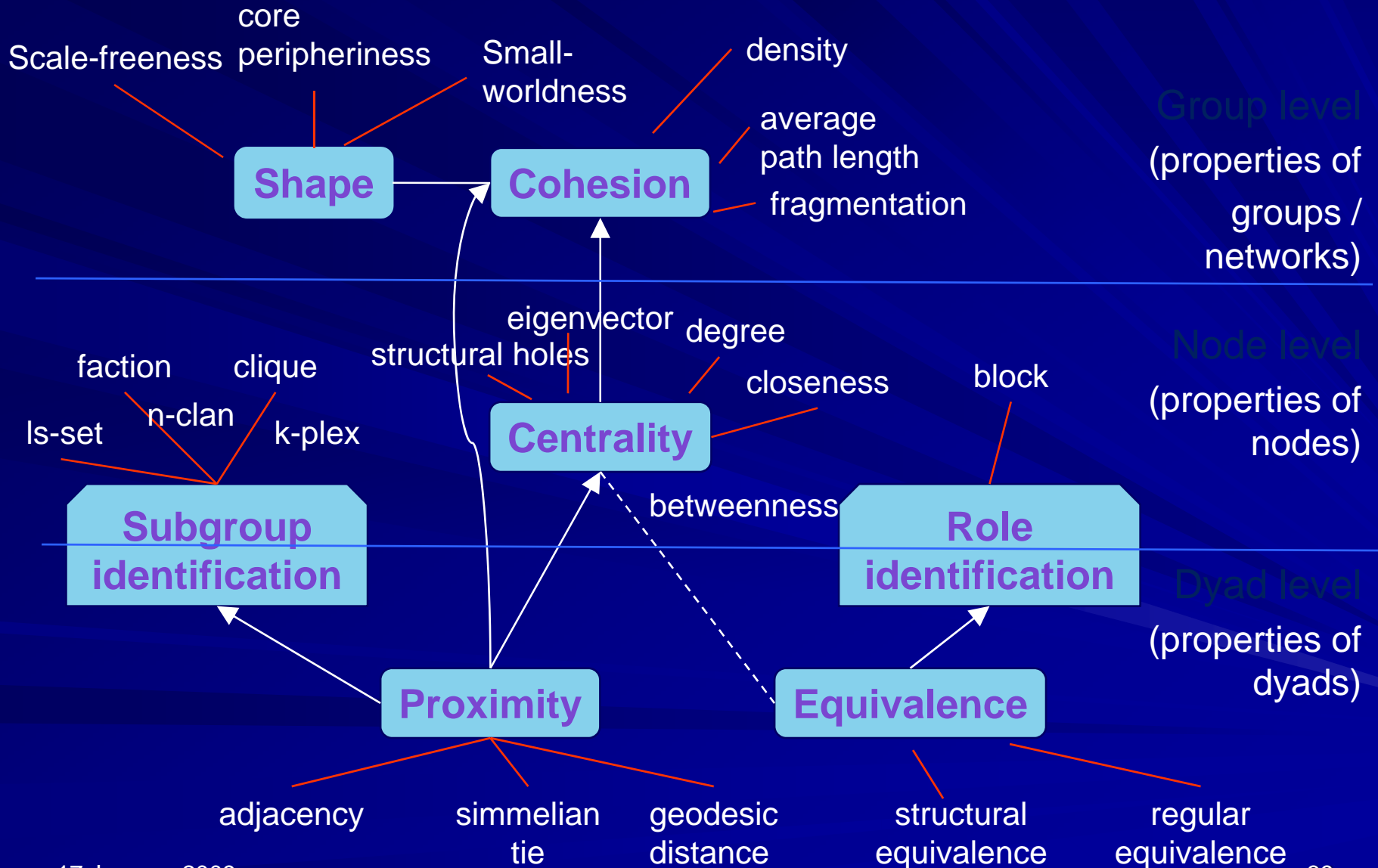
## ■ Node (actor) level

- Can aggregate to the node level (e.g., no. of friends)
- Or measure aspects of a node's position in the network

## ■ Group (network) level

- Aggregation to the group or whole network level (e.g., no. of ties within group)
- Or measure aspects of network shape (e.g. centralization)

# Family of Theoretical Constructs



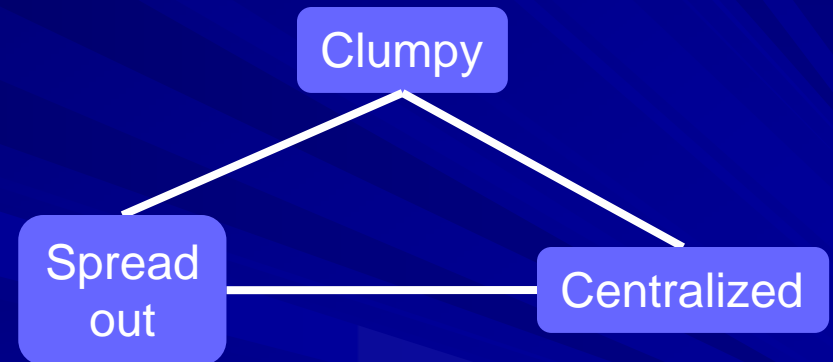
# Network/Group Properties

## Cohesion Concepts

- How “well connected” the network is, e.g.,
  - Number of ties
  - Shortness of paths
  - How difficult it is to disconnect the network by removing nodes

## Shape Concepts

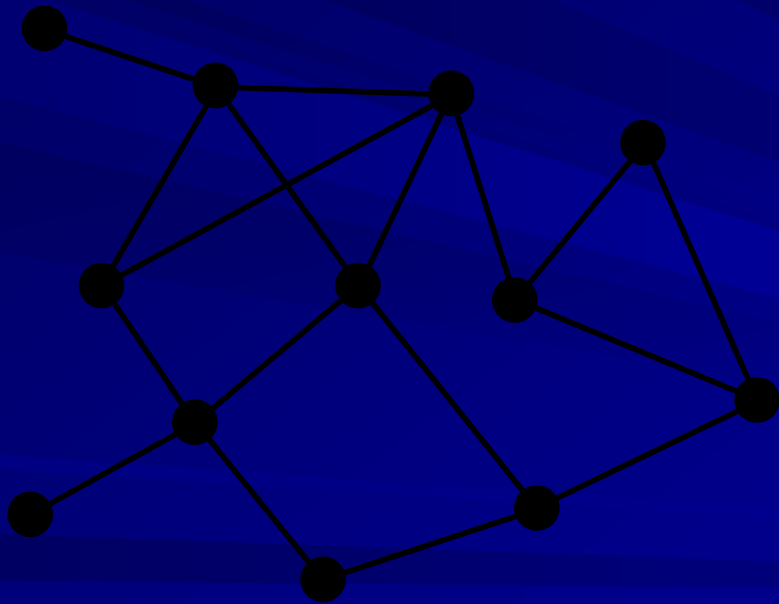
- What is the structure of the network?



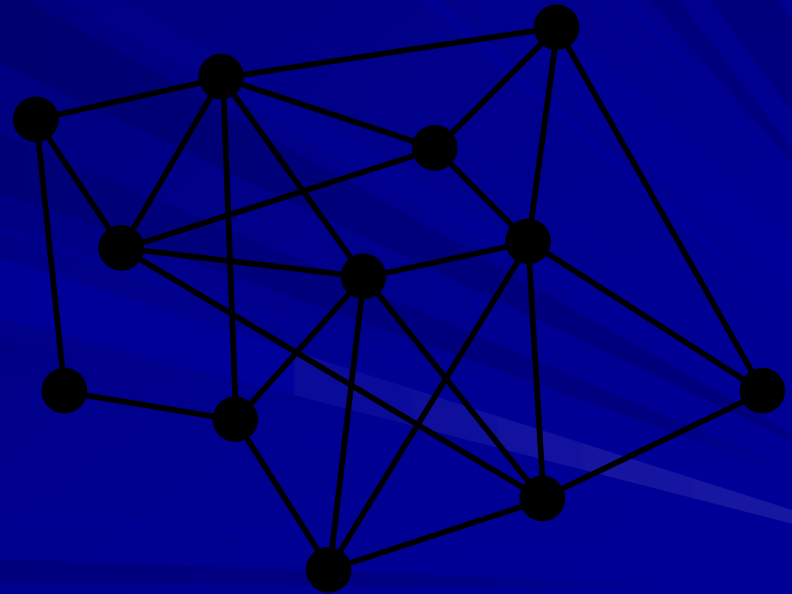


# Density of ties

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

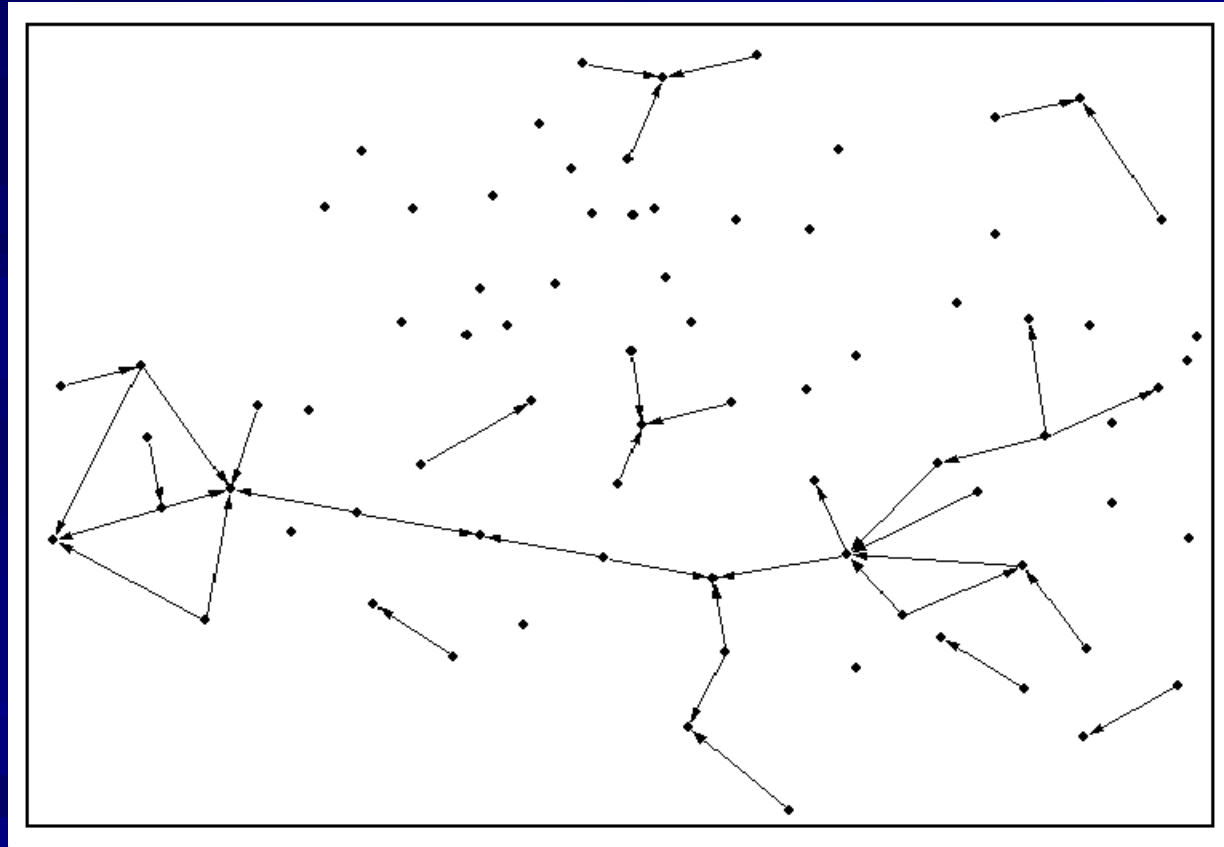


Low Density (25%)



High Density (39%)

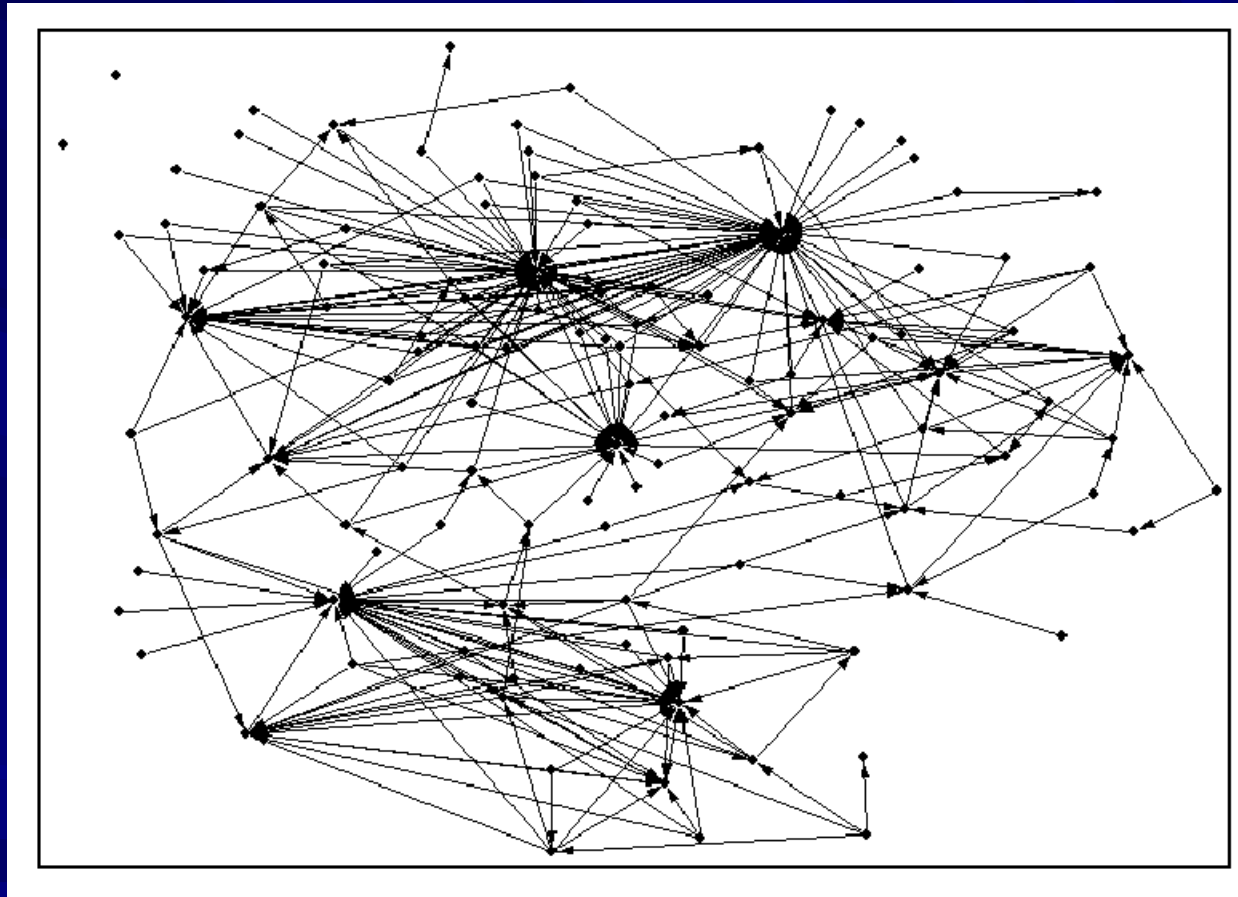
# Case Study: Entwistle et al study of help with the rice harvest



Village 1

Data from Entwistle et al

# Social Capital?



Village 2

Data from Entwistle et al

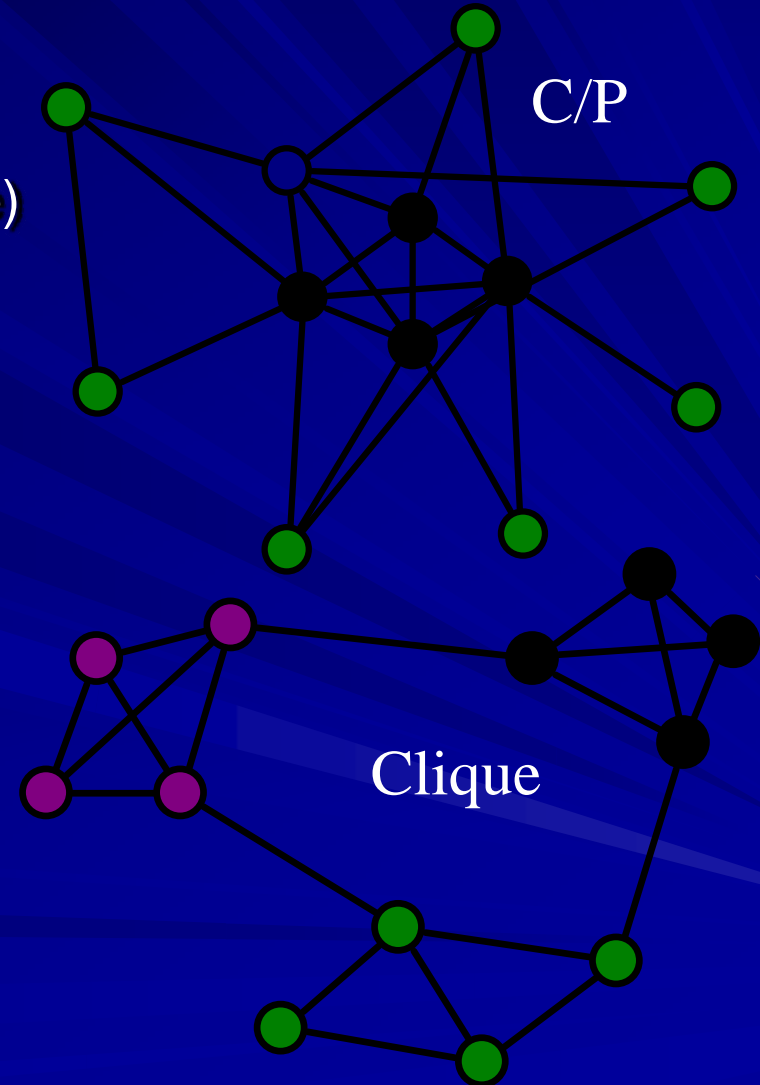
# Core/Periphery Structures

## ■ 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

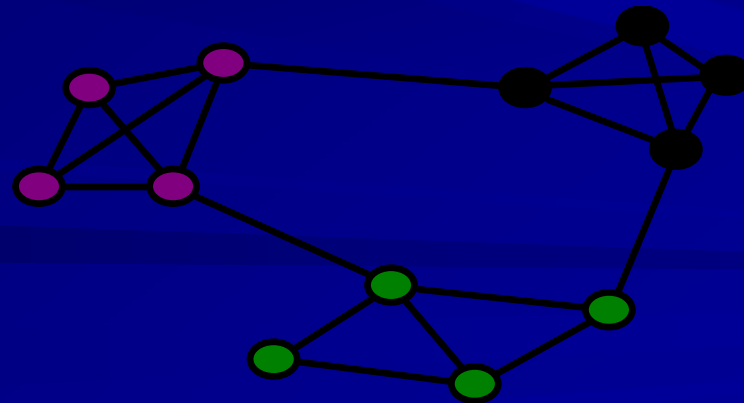
- Multiple subgroups or factions
- Identity with subgroup
- Diversity of norms, belief
- E.g., structure of social science



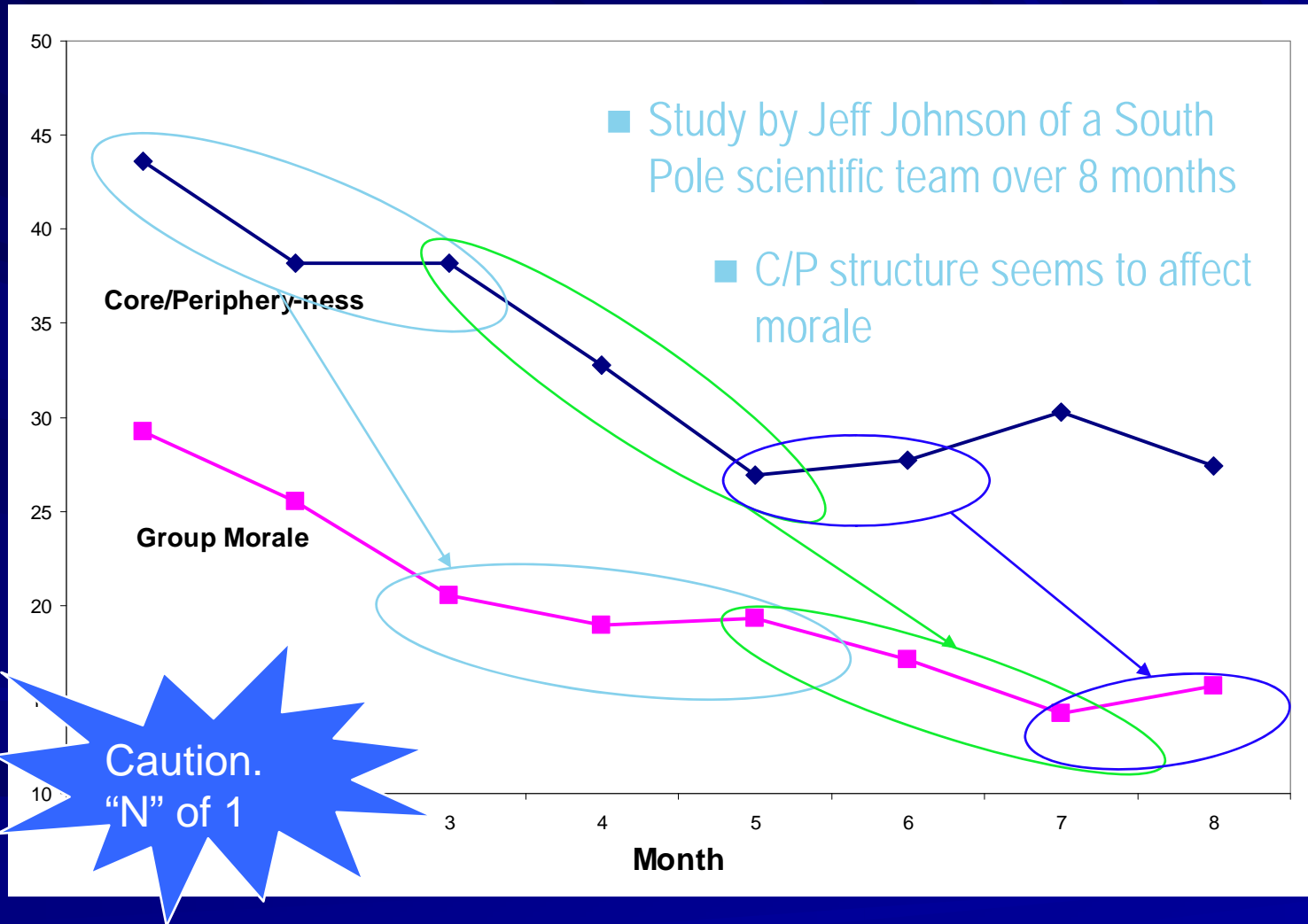
# On Innovation and Network Structure

"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



# Case Study: Johnson's study of morale at the South Pole





# Node Level Concepts

## Individual level social capital

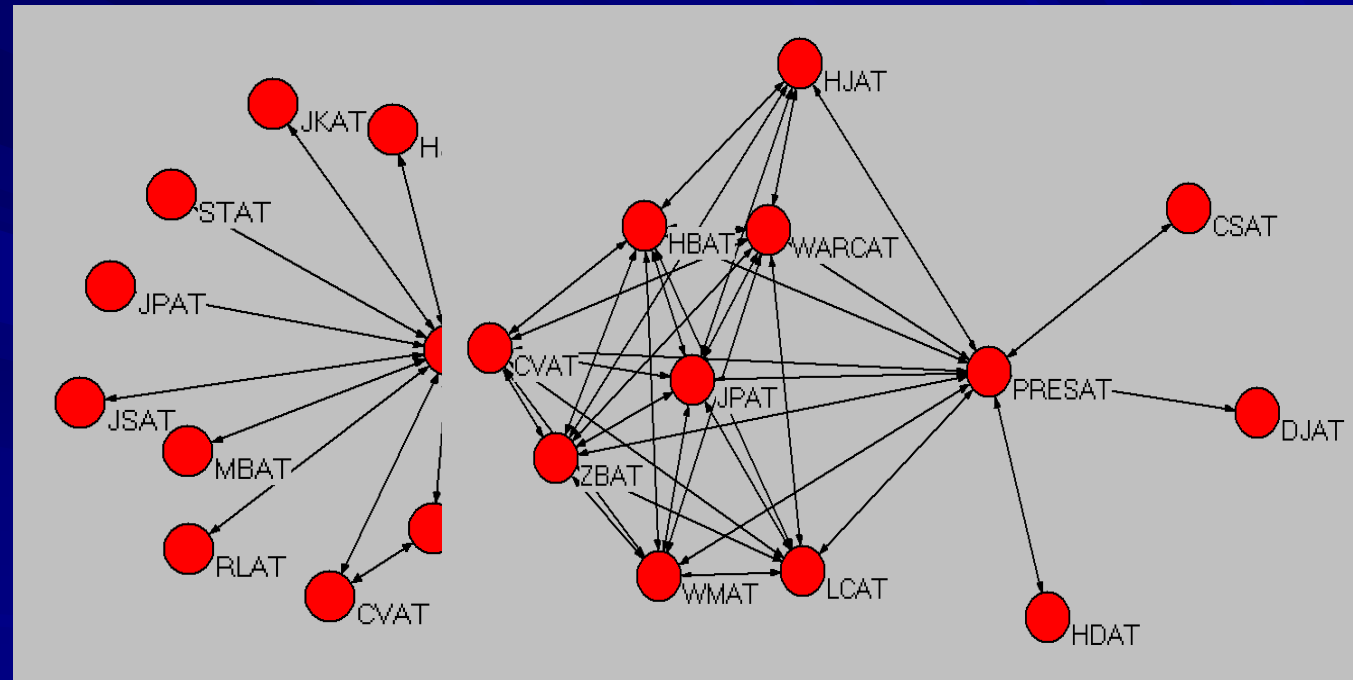
### ■ Centrality

- Betweenness: how often a node lies on shortest path between two others
- Closeness: how far away a node is on average from all others

### ■ Structural holes

- Extent to which a node's contacts are unconnected from each other

# Structural Holes



Year 1

Year 4

White House Diary Data, Carter Administration

Data courtesy of Michael Link

# Betweenness Centrality

- How often a node lies along the shortest path between two other nodes

- Defined as:

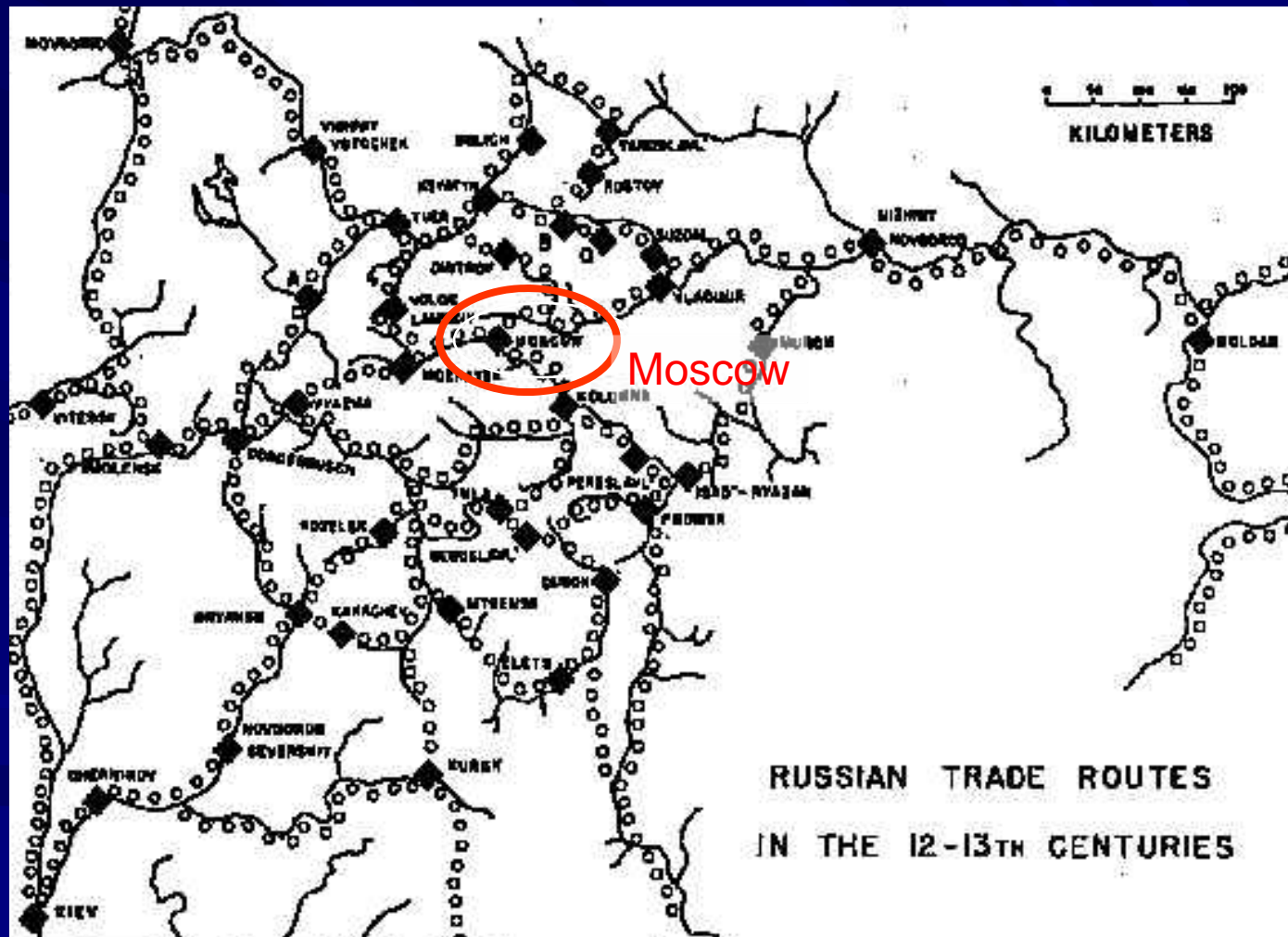
$$b_k = \sum_{i,j} \frac{g_{ikj}}{g_{ij}}$$

- 

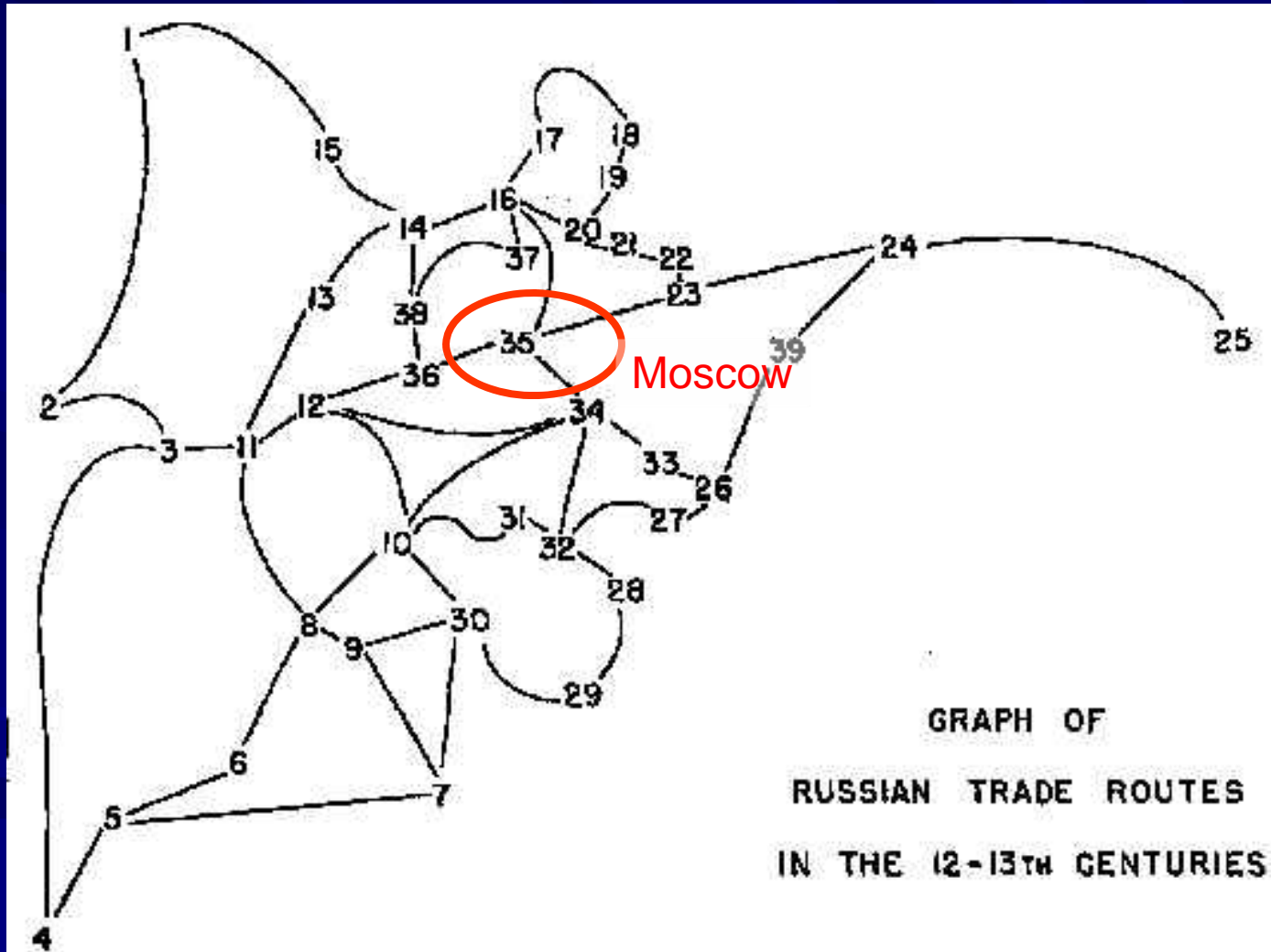
where  $g_{ij}$  is number of geodesic paths from  $i$  to  $j$  and  $g_{ikj}$  is number of those paths that pass through  $k$

- Seen as index of potential for gatekeeping, brokering, controlling the flow, and also of liaising otherwise separate parts of the network;
- Expected to correlate with power and access to diversity of what flows; potential for synthesizing

# Case Study: Pitts' analysis of Moscow's emergence to pre-eminence



# Moscow has highest betweenness in the river network



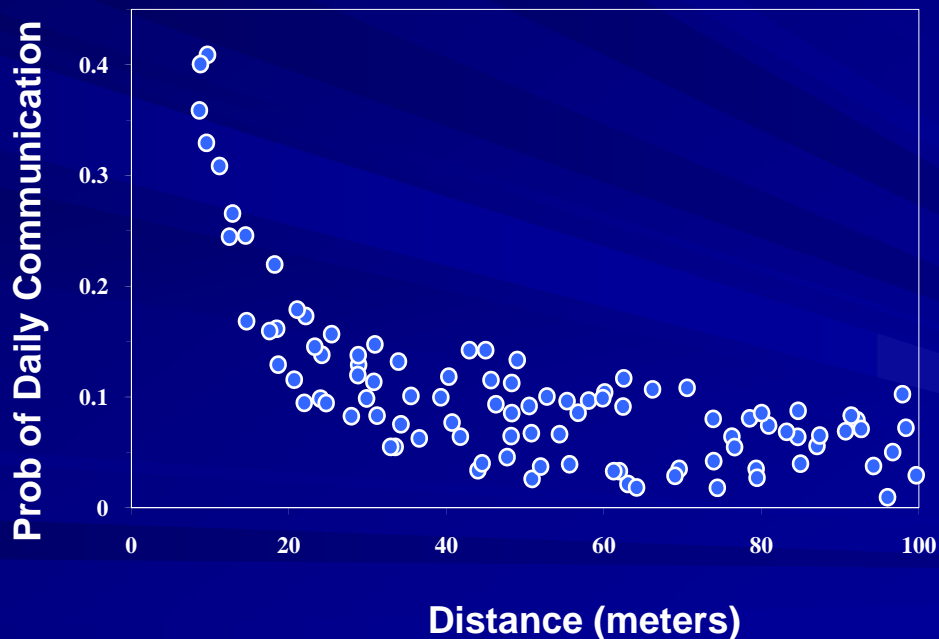
# Dyadic Level

- Properties of dyads
  - Raw network data
  - Degrees of separation
  - Multiplexity



# Dyad Level of Analysis

- Multiplexity
- Case Study: Tom Allen (1977) study of physical proximity and amount of communication



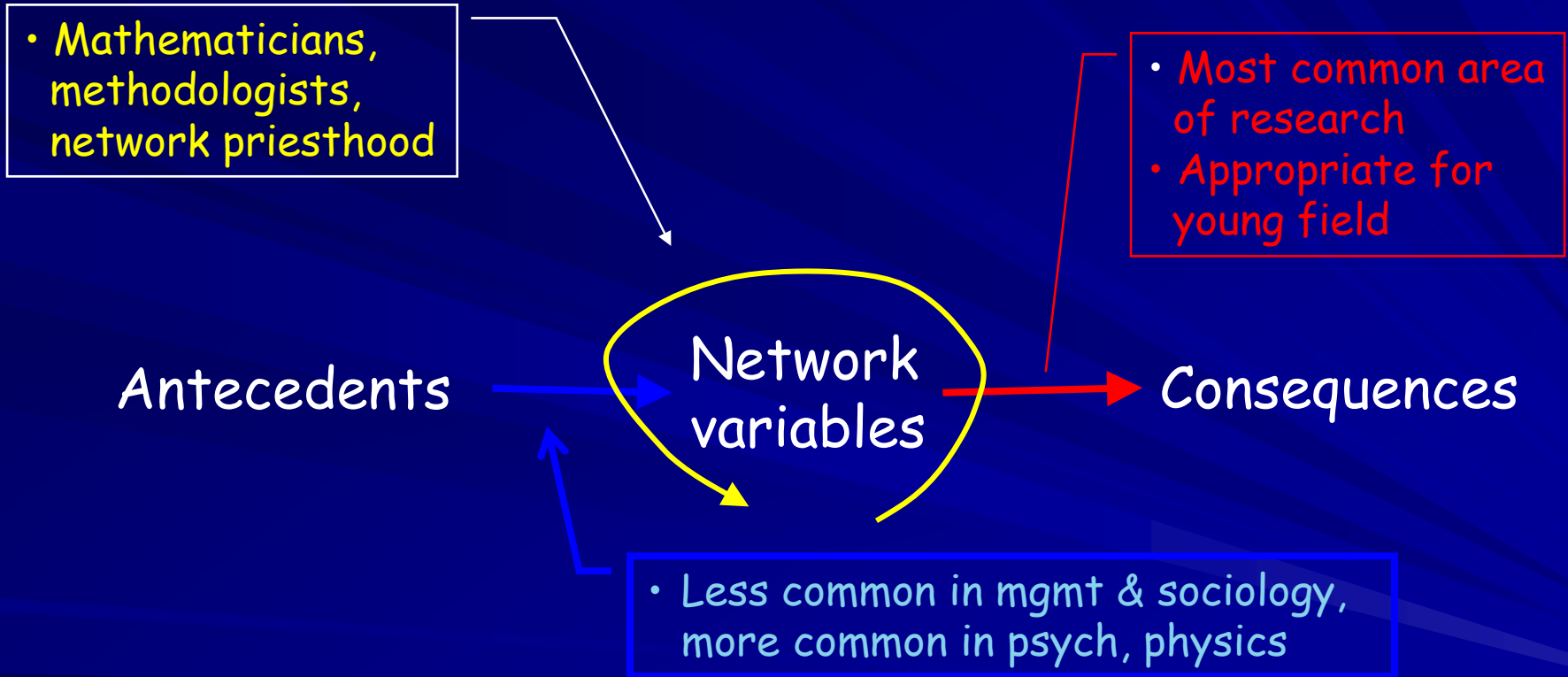
# Homophily

- Tendency to interact with or have positive relations with people who are similar to oneself along socially significant lines

Gender	Male	Female	Race	White	Black
Male	1245	748	White	3806	29
Female	970	1515	Black	40	283

Age	< 30	30 - 39	40 - 49	50 - 59	60 +
< 30	567	186	183	155	56
30 - 39	191	501	171	128	106
40 - 49	88	170	246	84	70
50 - 59	84	100	121	210	108
60 +	34	127	138	212	387

# Causality and Network Research



## TYPES OF SIMPLE HYPOTHESES

	Independent Variable	Dependent Variable	Example Study
Dyad Level	Network tie	Network tie	doing business w/ ea other → friendship
	Network tie	Attribute similarity	Friends → similar political attitudes
	Attribute similarity	Network tie	Smoking → friendship
Node Level	Node level network property	Node level network property	Degree → betweenness
	Node level network property	Actor attribute	Centrality → performance
	Actor attribute	Node level network property	Good looks → centrality
Group Level	Group level network property	Group level network property	Density → Avg path length
	Group level network property	Other group attribute	Density → team performance
	Other group attribute	Group level network property	Prop women → density of trust ties

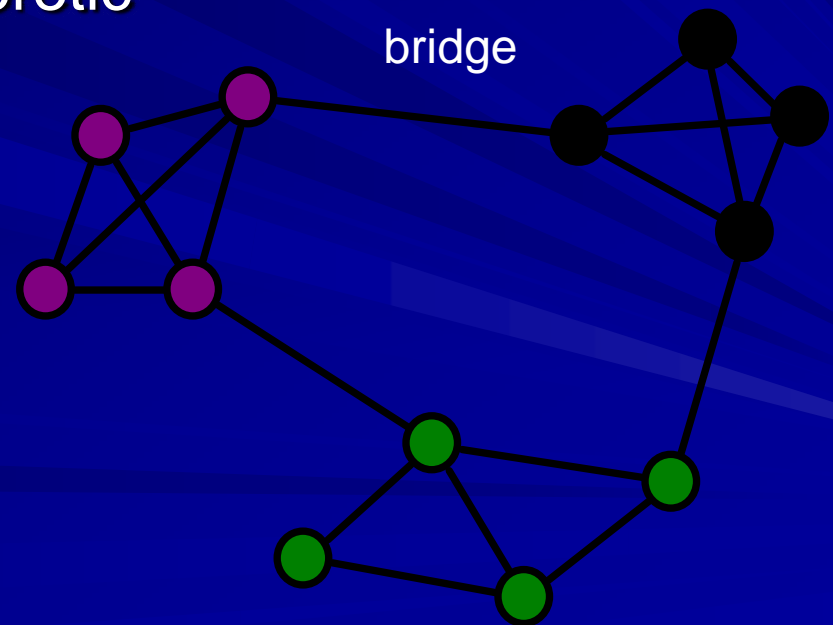
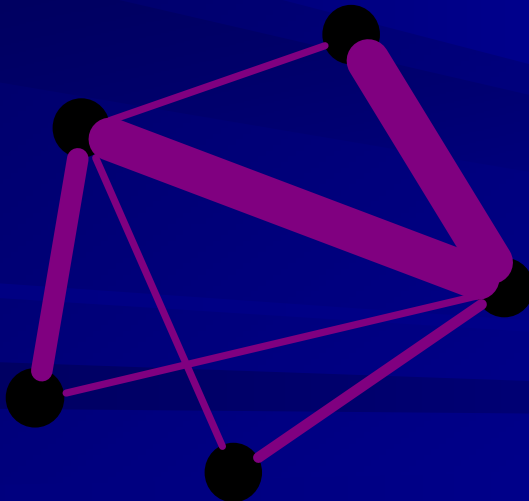
# Consequences of Network Variables

<div style="text-align: right; color: purple;">Ends</div> <div style="color: purple;">Means</div>	<b>Explaining Variance in Performance (social capital)</b>	<b>Explaining Social Homogeneity (adoption)</b>
<b>Connectionist mechanisms</b> (flows thru ties)	Success comes from obtaining resources <u>through</u> social ties; Lin's social resource theory	People have same behavior because they directly <b>influence</b> each other & transmit ideas, beliefs, etc.
<b>Topological mechanisms</b> (emergent properties of topology)	Network positions /shapes provide opportunities for exploitation; Burt's autonomy theory	People have same behavior because their network positions are similar (and affect them similarly); same <b>social environment</b>

Borgatti, S.P. and Foster, P. 2003. The network paradigm in organizational research: A review and typology. *Journal of Management*. 29(6): 991-1013

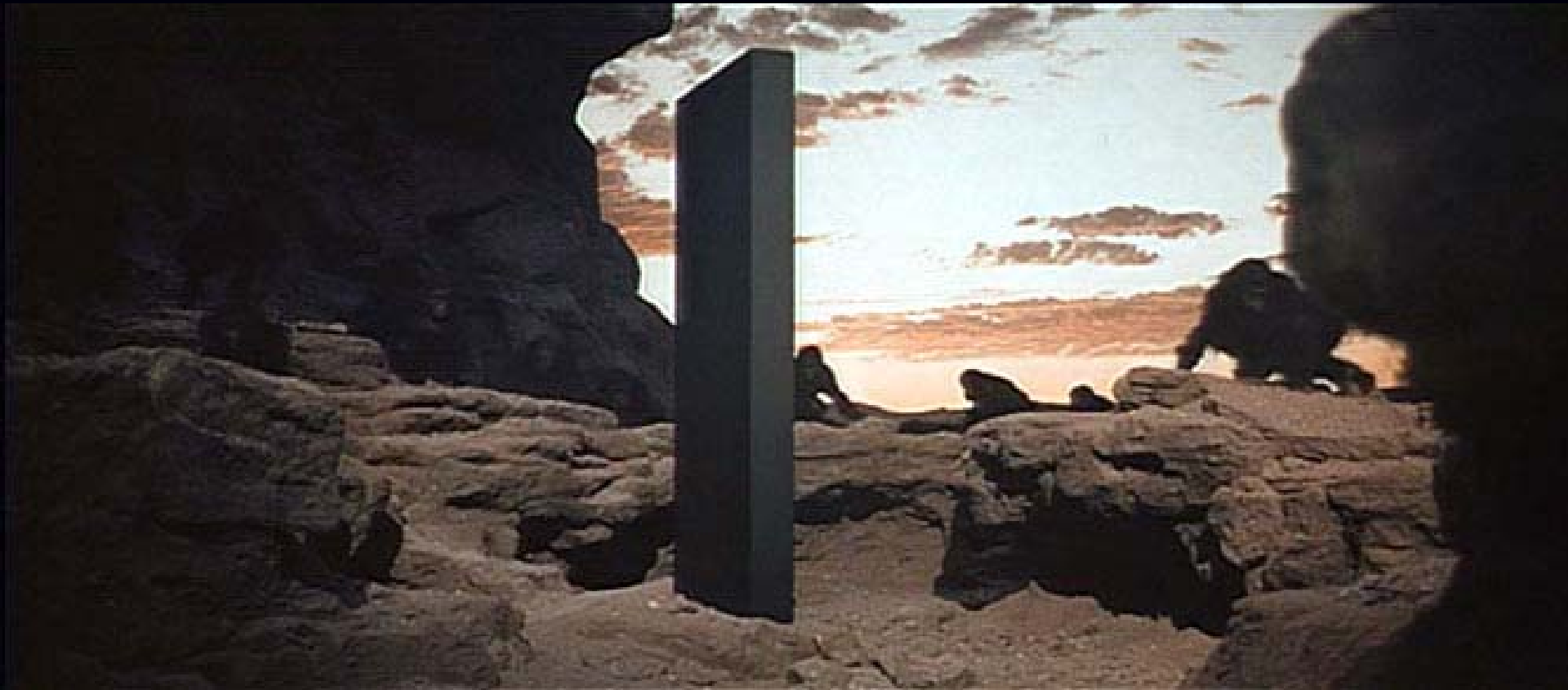
# An Example of Network Theorizing

- Granovetter's strength of weak ties (SWT) theory
  - If bridges tend to be the sources of novel information, and
  - If strong ties tend to create embeddedness, then
    - Weak ties tend to be the sources of novel information
- The argument is graph-theoretic





# The Frontier



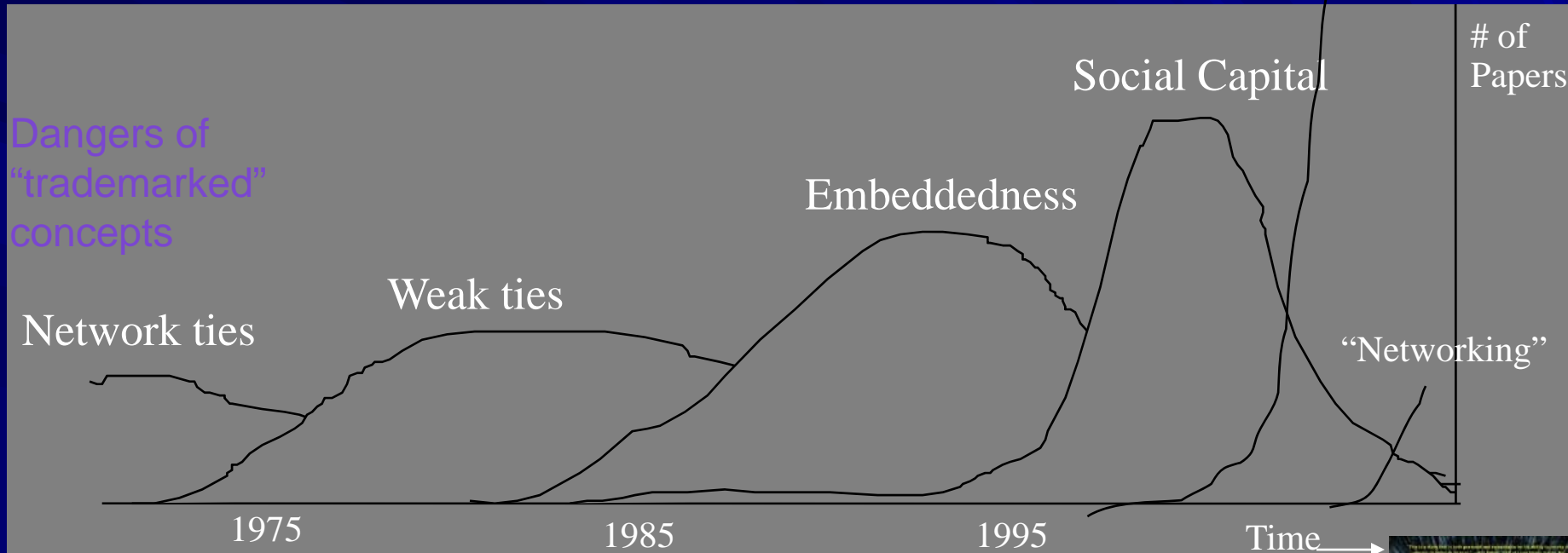
# Where the energy is

- Stochastic methods – ERGM, SIENA
- Analyzing transactions & interactions
- Network evolution
- Simulation, what-if analysis, optimization
- Automated data collection & imputation
  - Taking advantage of the google era
- Large networks

# Trends & Buzzwords

Is the field getting too popular too fast?

Small worlds  
Scale-free  
Communities?



WARNING: Totally made-up data! Do not take seriously!

Do fads sweep out equal areas under the graph?

