

# Social Network Analysis: Overview Part 1

EPIC - SNA, Columbia University

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University of Minnesota

Format and Overview of Course

What is Social Network Analysis?

Preliminaries: Why Networks?

Network Representations (Data Structures/Visualizations)

Review of R and Discussion of Network Data in R

References and Places for More Information

## **Format and Overview of Course**

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# Format of the Course

## (Most Days)

- 1 hour lecture
- 1 hour lab
- Break (5-10 minutes)
- 1 hour lecture
- 1 hour lab

# Overview of this Course

- Day 1 - Overview of Networks and Introduction to R for analysis
- Day 2 - Network Descriptives
- Day 3 - More Network Descriptives and Introduction to Statistical Inference for Networks
- Day 4 - Introduction to Statistical Models
- Day 5 - Advanced Statistical Models: Network Autocorrelation, TERGM and SAOM

# About these notes

Portions of material adapted from courses by:

- jimi adams, University of Colorado, Denver
- Carter Butts, UCI

&

- David Schaefer, Arizona State University
- Ryan Light, University of Oregon
- Ann McCranie, Indiana University
- Benjamin Lind, HSE-Moscow
- Daniel McFarland, Stanford University
- David Knoke, University of Minnesota
- Garry Robins, University of Melbourne
- Krista Gile, University of Massachusetts
- Lada Adamic, University of Michigan
- Michał Bojanowski, University of Warsaw
- Mark Handcock, UCLA
- Mark Newman, University of Michigan
- James Moody, Duke University
- Martina Morris, University of Washington
- Ryan Acton, University of Massachusetts

# What is Social Network Analysis?

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# What is Social Network Analysis?

- A **theoretical perspective** that attempts to explain how individual and group behaviors and relations are linked to patterns in society
- A set of relational **methods** for systematically analyzing the ties/relations between nodes/actors

Borgatti, SP., A Mehra, DJ Brass, & G Labianca. 2009. "Network Analysis in the Social Sciences." *Science* 323:892

# What is Social Network Analysis?

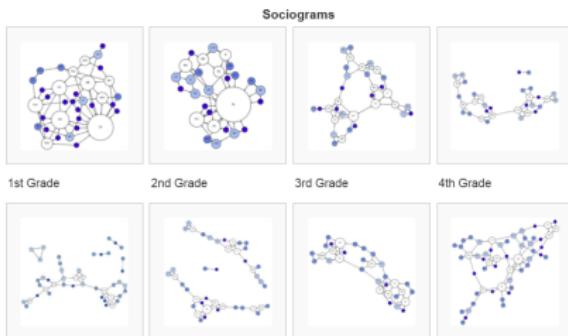
- A **theory** and a **method** for social scientific analysis that relies on:
  - *Structural* intuition
  - Systematic collection of *relational* data
  - Use of graphic *visualizations*
  - Mathematical or computational *models*

Freeman, Linton C. 2004. The Development of Social Network Analysis. Empirical Press.

# What is Social Network Analysis?

## The origins: Moreno (1934)

His 1934 book *Who Shall Survive?* contains some of the earliest graphical depictions of social networks (sociograms). In this book, he introduced a famous explanation, why a pandemic of runaways emerged at the [New York Training School for Girls](#) in Hudson.



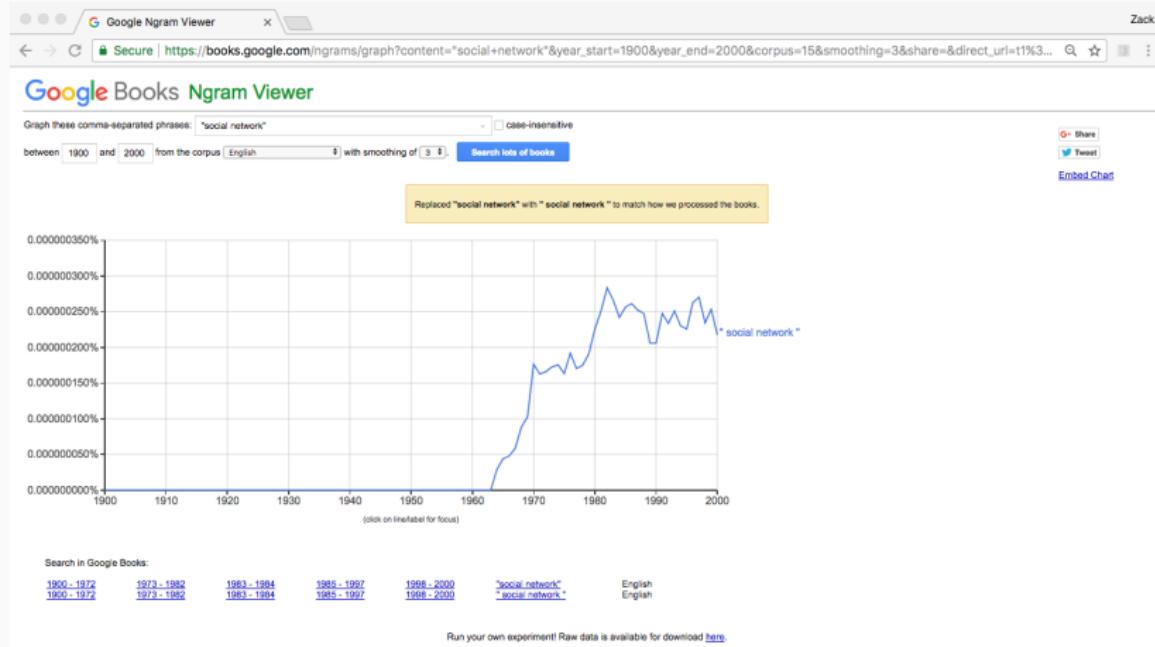
Jacob L. Moreno  
Psychotherapy

Jacob Levy Moreno was an Austrian-American leading psychiatrist and psychosociologist, thinker and educator, the founder of psychodrama, and the foremost pioneer of group psychotherapy. [Wikipedia](#)

<http://www.asgpp.org/docs/wss/wss.html>

Martina Morris. Statistical Models for Social Networks. University of Washington.

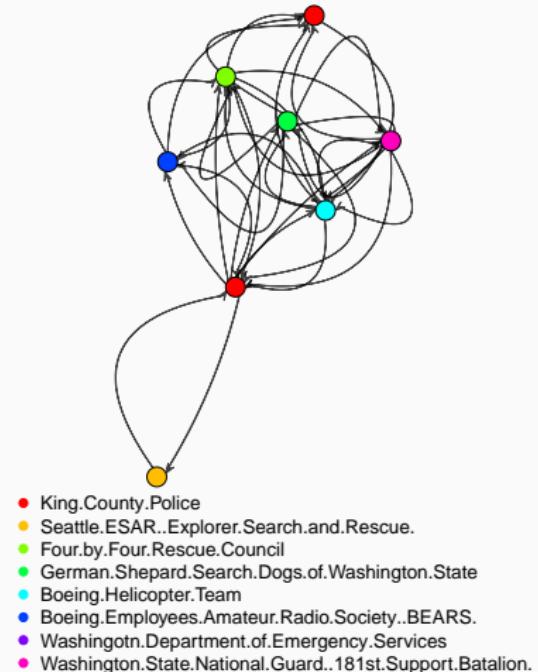
# What is Social Network Analysis?



# What is Social Network Analysis?

- Relational (network) data concerns connections among entities, rather than attributes of entities
  - **Entities** can be persons, organizations, concepts, etc.
  - **Relations** can be interaction, proximity, membership, etc.

Mt. Si Search and Rescue Emergent  
Multi-organizational Network



Drabek, T.E.; Tamminga, H.L.; Kilijanek, T.S.; and Adams, C.R. (1981). Data from Managing Multiorganizational Emergency Responses: Emergent Search and Rescue Networks in Natural Disaster and Remote Area Settings. Program on Technology, Environment, and Man Monograph 33. Institute for Behavioral Science, University of Colorado.

## Preliminaries: Why Networks?

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## Some Types of Networks

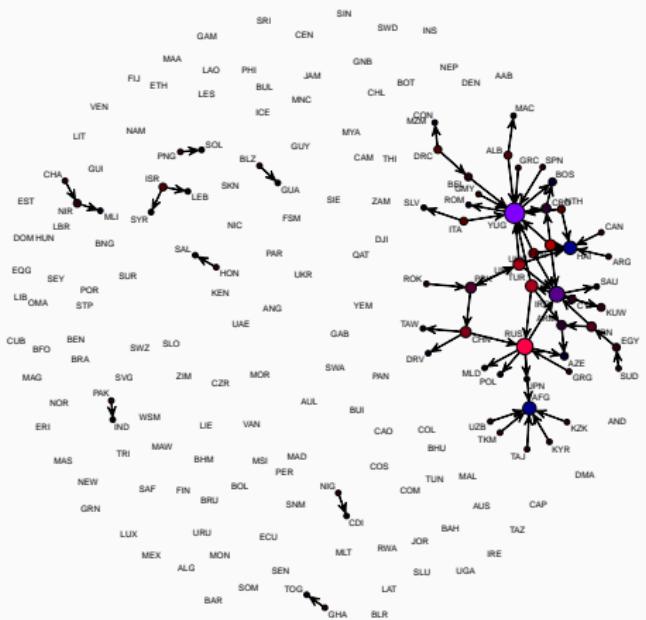
- Conceptual: shared or antithetic properties
  - E.g., similarity/difference in individual attributes, correlation among variables, inclusion/exclusion, surface matchings on proteins
- Co-categorical: shared membership
  - E.g., organizational co-membership, event co-participation, co-occurrence of words within texts
- Nominal: resulting from the behavior of respondent (**ego**)
  - E.g., attributions of friendship/enmity, kinship (fictive or otherwise), causal narratives, reported sexual contact networks, reported needle sharing
- Behavioral
  - E.g., face-to-face communication, radio communication, physical contact
- Online Social networks
  - E.g., Facebook, Twitter, LinkedIn

# Examples!

Now let's look at some examples...

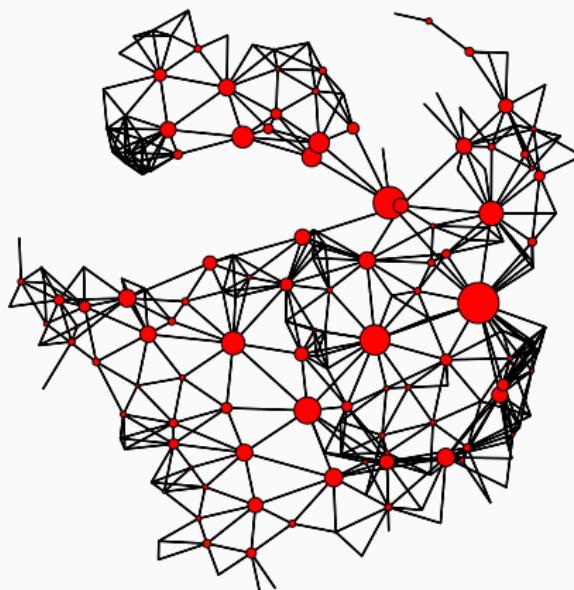
# Correlates of War Project: Militarized Interstate Disputes

### 1993 militarized interstate disputes (MIDs)

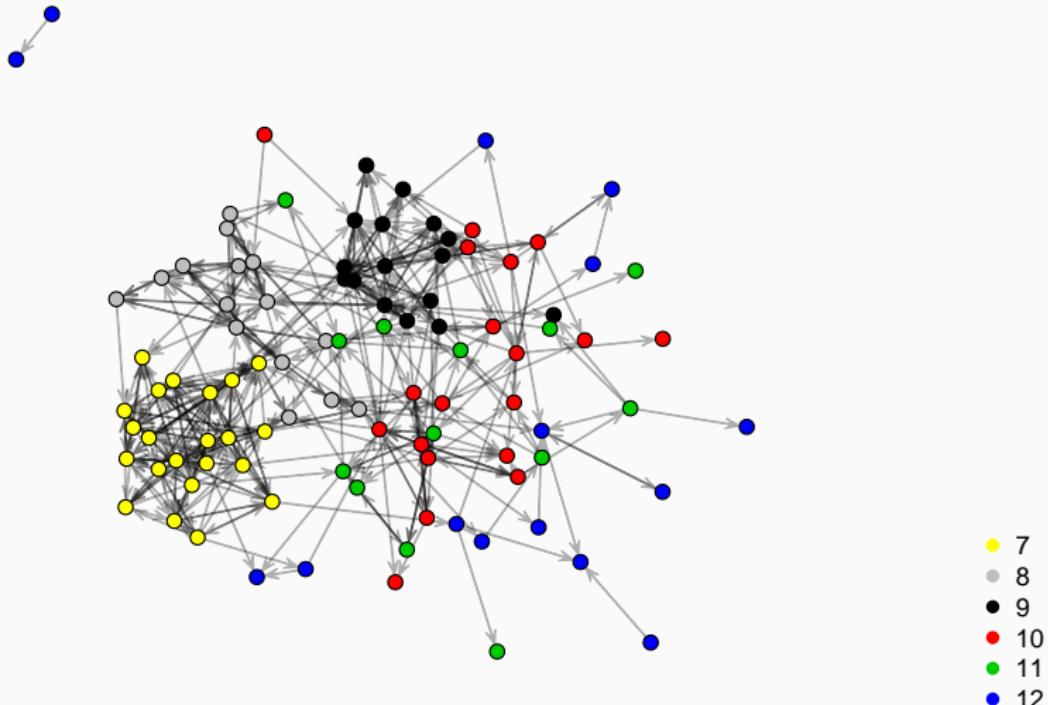


# Correlates of War Project: Contiguity Network

Contiguity Network, 1993



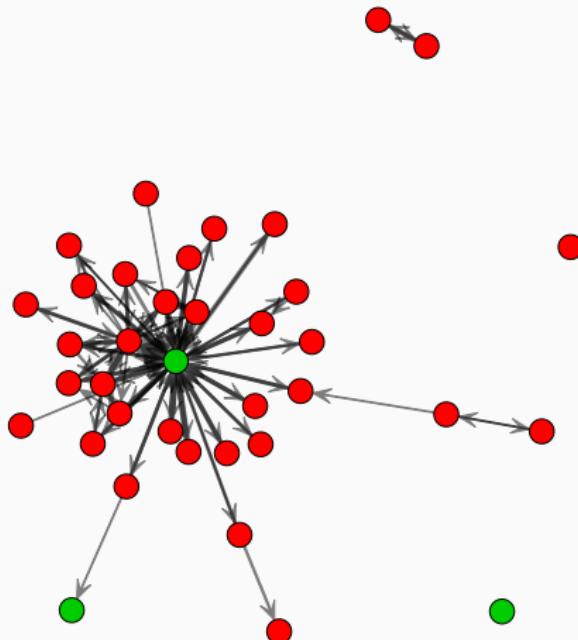
# Faux Desert High (Simulation of an Add Health HS)



Hunter, D. R., Handcock, M. S., Butts, C. T., Goodreau, S. M., & Morris, M. (2008). ergm: A package to fit, simulate and diagnose exponential-family models for networks. *Journal of statistical software*, 24(3).

# World Trade Center Radio Communication

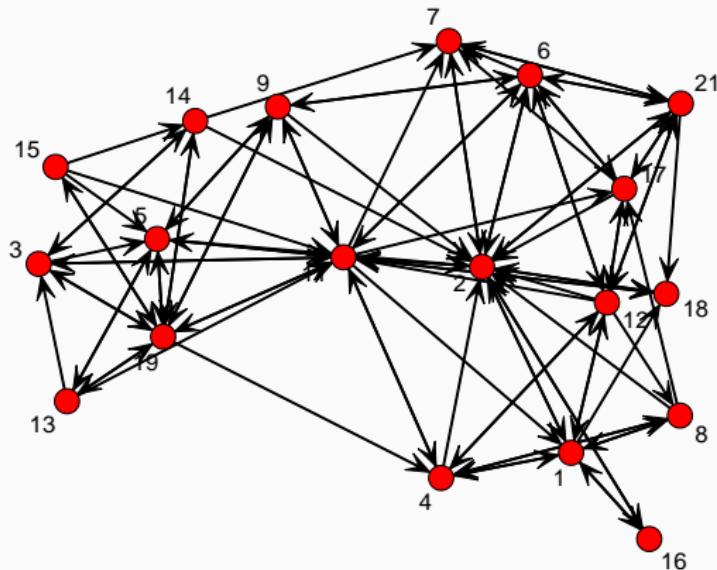
Responder Communication Network



Butts, C. T., Petrescu-Prahova, M., & Remy Cross, B. (2007). Responder communication networks in the World Trade Center disaster: Implications for modeling of communication within emergency settings. *Mathematical Sociology*, 31(2), 121-147.

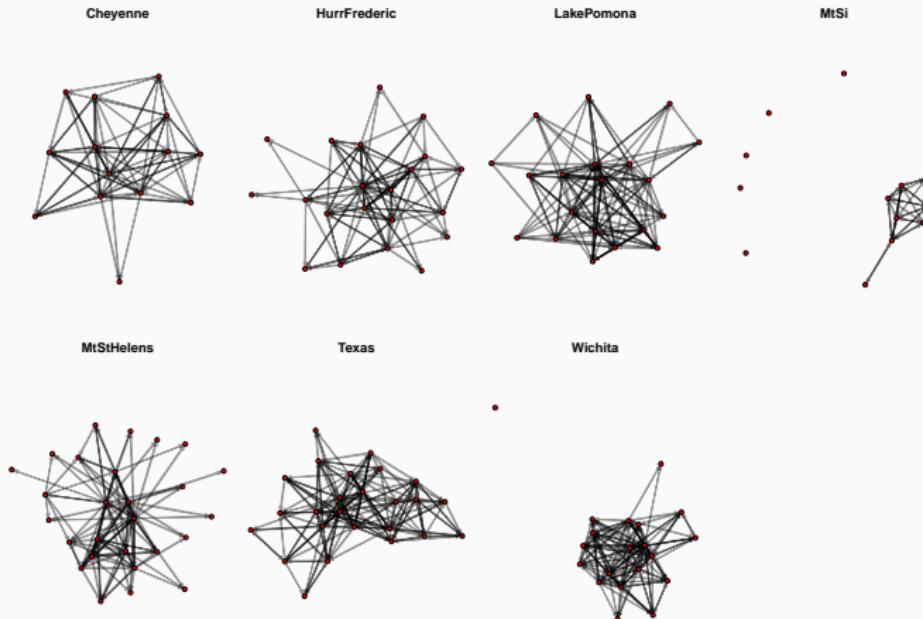
# David Krackhardt's Perceived Friendships

## Consensus Model of Perceived Friendships in an Organization



Krackhardt, D. (1987). Cognitive social structures. Social networks, 9(2), 109-134.

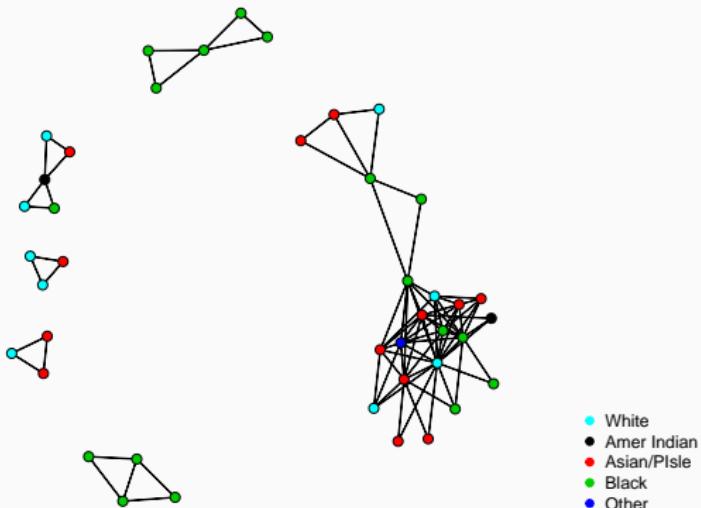
# SAR EMONs, All Reported Ties, from Drabek et al 1981



Marcum, C. S., Bevc, C. A., & Butts, C. T. (2012). Mechanisms of control in emergent interorganizational networks. *Policy Studies Journal*, 40(3), 516-546.

# Needle Network

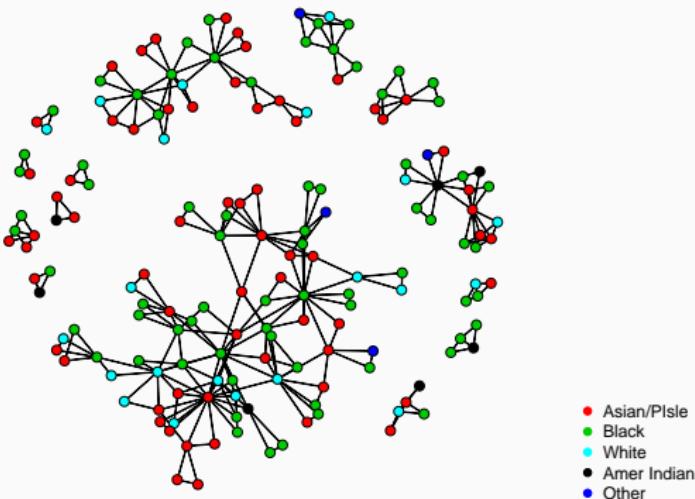
Rural Arizona Risk Networks: Needle Sharing



Morris, Martina, and Rothenberg, Richard. HIV Transmission Network Metastudy Project: An Archive of Data From Eight Network Studies, 1988–2001. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2011-08-09. <https://doi.org/10.3886/ICPSR22140.v1>

# Sexual Contact Network

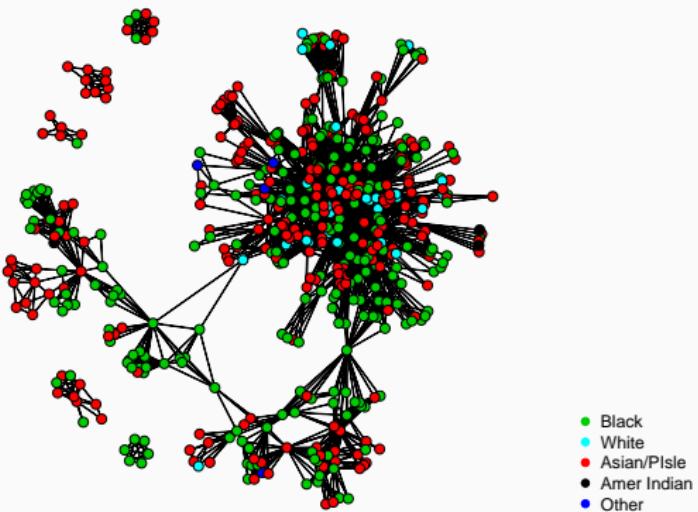
Rural Arizona Risk Networks: Sex



Morris, Martina, and Rothenberg, Richard. HIV Transmission Network Metastudy Project: An Archive of Data From Eight Network Studies, 1988–2001. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2011-08-09. <https://doi.org/10.3886/ICPSR22140.v1>

# Social Contact Network

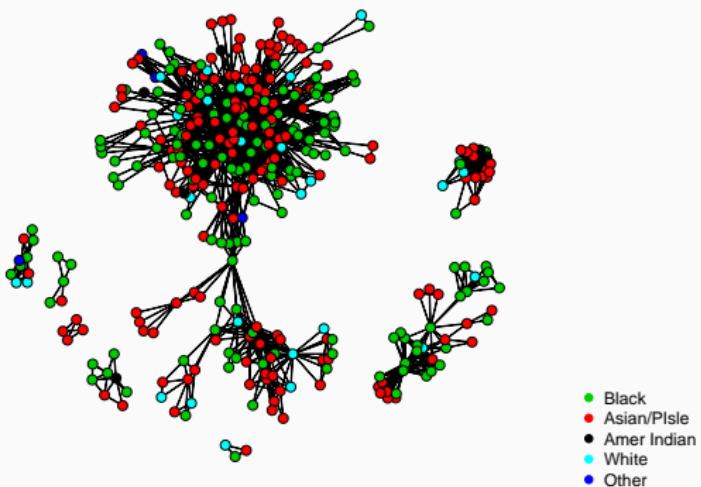
Rural Arizona Risk Networks: Social



Morris, Martina, and Rothenberg, Richard. HIV Transmission Network Metastudy Project: An Archive of Data From Eight Network Studies, 1988–2001. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2011-08-09. <https://doi.org/10.3886/ICPSR22140.v1>

# Drug Contact Network

Rural Arizona Risk Networks: Drug



Morris, Martina, and Rothenberg, Richard. HIV Transmission Network Metastudy Project: An Archive of Data From Eight Network Studies, 1988–2001. Ann Arbor, MI: Inter-university Consortium for Political and Social Research [distributor], 2011-08-09. <https://doi.org/10.3886/ICPSR22140.v1>

# **Network Representations (Data Structures/Visualizations)**

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# Defining Terms: A Basis in Graph Theory

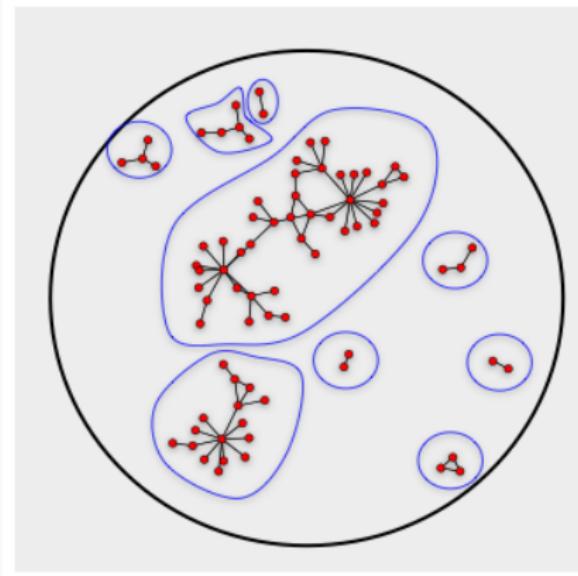
- Points (or nodes/vertices)
  - In social science – “actors”
    - People, organizations, nation-states, mobs, papers, ideas
  - In other settings – “entities”
    - Animals, locations, objects
- Lines (or ties/relations) – interaction b/t nodes
  - These can be directed (arcs), non-directed (edges) and/or valued (counts/weights)
  - Social:
    - Friend, relative, neighbor, conversation partner, email sender/recipient, co-member, citations
  - Other:
    - Grooming behavior, traversal patterns, etc.

Borgatti, SP. 1994. "A Quorum of Graph Theoretic Concepts." Connections 17:47-49.

# Defining Terms: A Basis in Graph Theory

## Network, graph, sociogram

- Aggregate of ALL nodes AND ties for entire population in a single representation
  - directed (digraph) or un-directed (graph)
  - Can be dissected into a variety of **subgraphs**
- Mathematical notation,  
 $G = (V, E)$

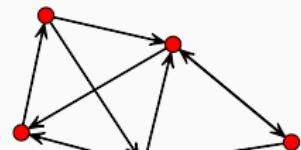


Borgatti, SP. 1994. "A Quorum of Graph Theoretic Concepts." Connections 17:47-49.

# Relational Data

	1	2	3	4	5
1	0	1	0	1	0
2	0	0	1	1	0
3	1	0	0	0	0
4	0	0	1	0	1
5	0	1	0	1	0

	1	2	3	4	5
1	1				
2		2			
3			3		
4				4	
5					5



- A collection of entities and a set of measured relations between them
  - **Entities**: nodes, actors, egos, units, respondents
  - **Relations**: ties, links, edges
- Relations can be
  - Directed or undirected
  - Valued or dichotomous (binary)

# Relational Data

Adjacency Matrix

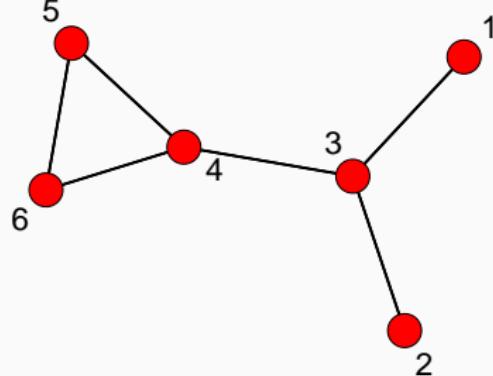
	1	2	3	4	5	6
1		0	1	0	0	0
2	0		1	0	0	0
3	1	1		1	0	0
4	0	0	1		1	1
5	0	0	0	1		1
6	0	0	0	1	1	

- Self-ties are known as "loops"
- Typically ignored

Edge List (Arc List)

snd	rec
1	1
3	1
2	2
3	2
1	3
2	3
3	3
4	3
3	4
4	4
5	4
6	4
4	5
5	5
6	5
4	6
5	6
6	6

Graph



# Relational Data

Friendship Nomination

Adjacency Matrix

	1	2	3	4	5	6
1		1	1	0	0	0
2	2		1	0	0	0
3	0	1		2	0	0
4	0	0	2		1	0
5	0	0	0	0		0
6	0	0	0	1	2	

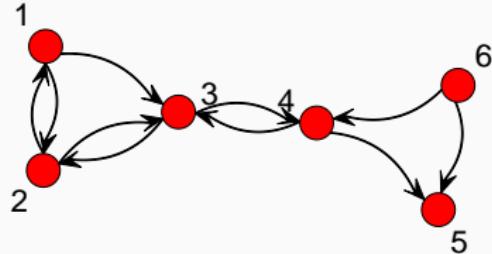
Friendship Nomination

Edge List (Arc List)

snd	rec
2	1
1	2
3	2
1	3
2	3
4	3
3	4
6	4
4	5
6	5

Friendship Nomination

Graph



# Relational Data

Friendship Nomination

Adjacency Matrix (Weighted)

	1	2	3	4	5	6
1		1	1	0	0	0
2	2		1	0	0	0
3	0	1		2	0	0
4	0	0	2		1	0
5	0	0	0	0		0
6	0	0	0	1	2	

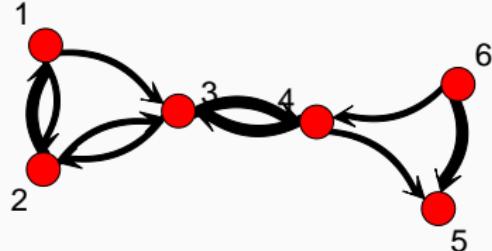
Friendship Nomination

Weighted Edge List (Arc List)

rnd	rec	val
2	1	2
1	2	1
3	2	1
1	3	1
2	3	1
4	3	2
3	4	2
6	4	1
4	5	1
6	5	2

Friendship Nomination

Graph



# Relational Data

Friendship Nomination

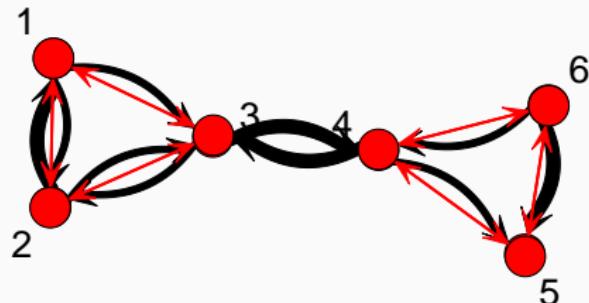
Adjacency Matrix (Weighted)

	1	2	3	4	5	6
1		1	1	0	0	0
2	2		1	0	0	0
3	0	1		2	0	0
4	0	0	2		1	0
5	0	0	0	0		0
6	0	0	0	1	2	

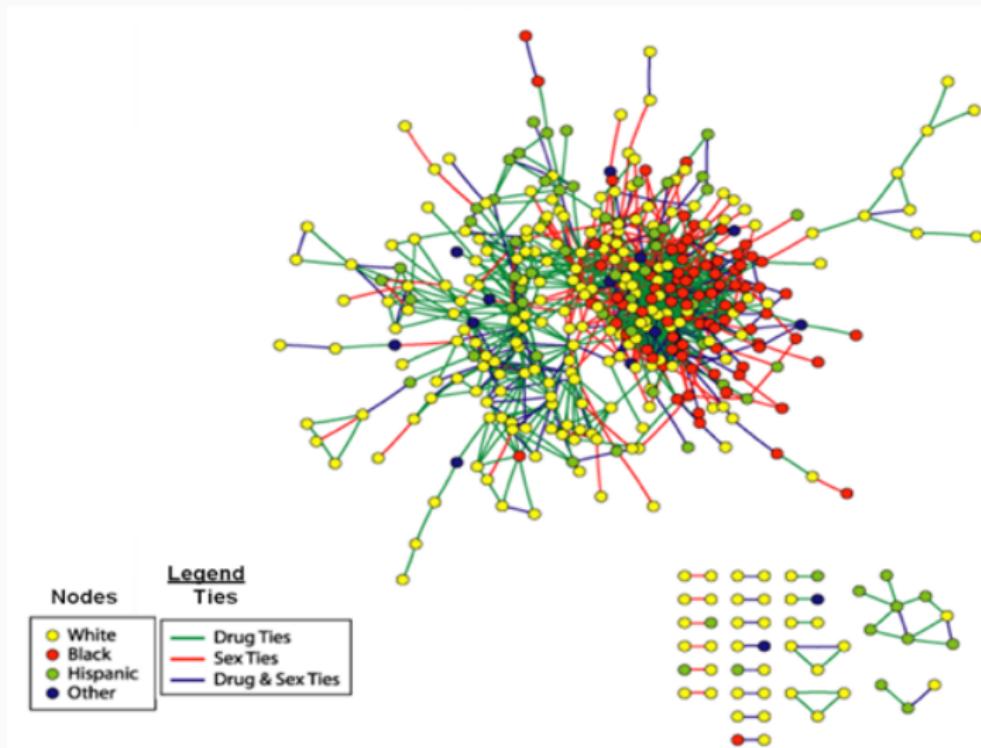
Family Nomination

	1	2	3	4	5	6
1		1	1	0	0	0
2	1		1	0	0	0
3	1	1		0	0	0
4	0	0	0		1	1
5	0	0	0	1		1
6	0	0	0	1	1	

Friendship Nomination

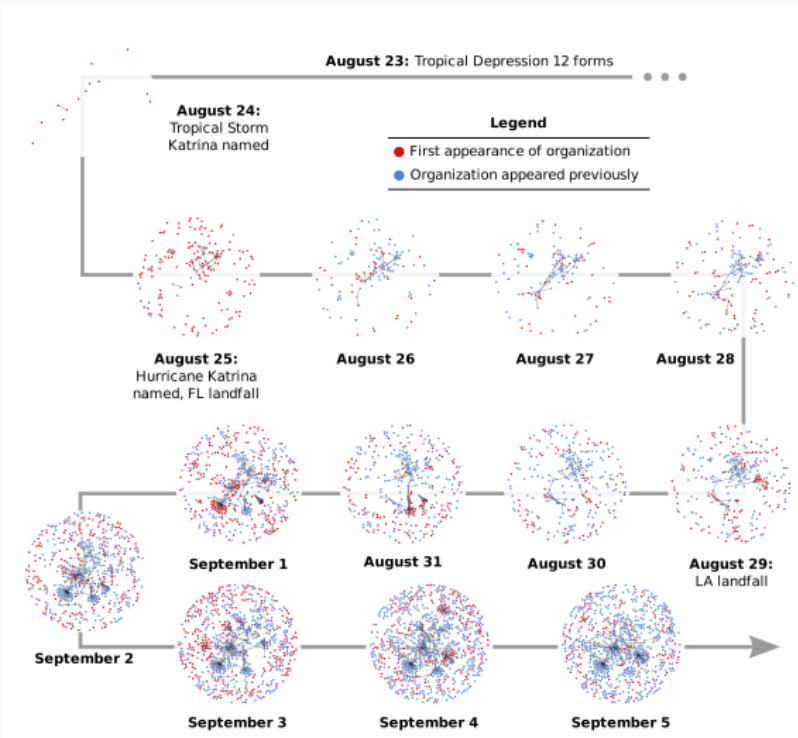


# Relational Data: Multiplexity



adams j, Moody J, Morris M. "Sex, Drugs, and Race: How Behaviors Differentially Contribute to Sexually Transmitted Infection Risk Network Structure." AJPH 2013;103(2):322-9.

# Relational Data: Network Change



Butts, C. T., Acton, R. M., & Marcum, C. S. (2012). Interorganizational Collaboration in the Hurricane Katrina Response. *Journal of Social Structure*, 13.

## Common Features of Interest

Beyond nodal and dyadic attributes, many networks exhibit the following features:

- **Reciprocity** of ties
- **Degree heterogeneity** among actors
  - Sociability, Popularity
- **Homophily** by actor attributes
  - Higher propensity to form ties between actors with similar attr
- **Transitivity** of relationships
  - Friends of friends have a higher propensity to be friends
- **Balance** of relationships
  - Liking those who dislike whom you dislike
- **Equivalence** of nodes
  - Some nodes may have identical/similar patterns of relationships

# How to Think about Network Data

Similarities			Social Relations					Interactions	Flows
Location	Membership	Attribute	Kinship	Other role	Affective	Cognitive	e.g., Sex with	e.g., Information	
e.g., Same spatial and temporal space	e.g., Same clubs	e.g., Same gender	e.g., Mother of Sibling of	e.g., Friend of Boss of Student of Competitor of	e.g., Likes Hates etc.	e.g., Knows Knows about Sees as happy etc.	Talked to Advice to Helped Harmed etc.	Beliefs Personnel Resources etc.	

**Fig. 3.** A typology of ties studied in social network analysis.

James Moody."Introduction to Social Network Analysis - Duke Sociology"

## Kinds of Network Data

	Complete	Ego
1-mode	Ties among “all” members of a single class of entities	Ties among the set of nodes (alters) directly tied to a specific individual (ego)
2-mode	Ties between all members of two different classes of entities	Ties between two sets of entities tied to a specific individual

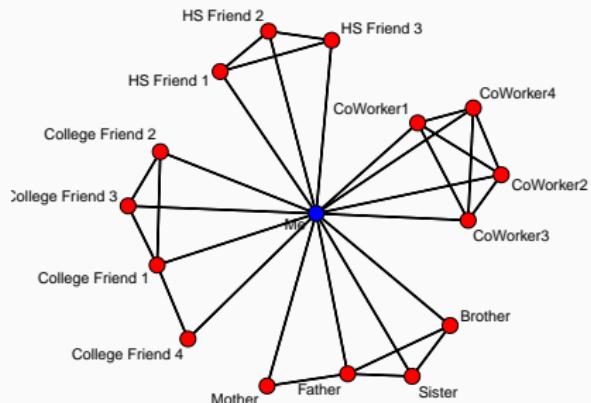
# Frameworks (Orientation)

- Methodological Aims
- Level of Analysis
- Unit of Analysis
- Theoretical Motivations
  - Descriptive
  - Analytic

Knoke D, Yang S. Social Network Analysis: Sage; 2007.

# Level of Analysis: Sampling

- Ego-Networks
  - A respondent and the set of people they have relationships with
- Measures:
  - Size
  - Density
  - Types of Relationships
  - Similarity
  - Composition

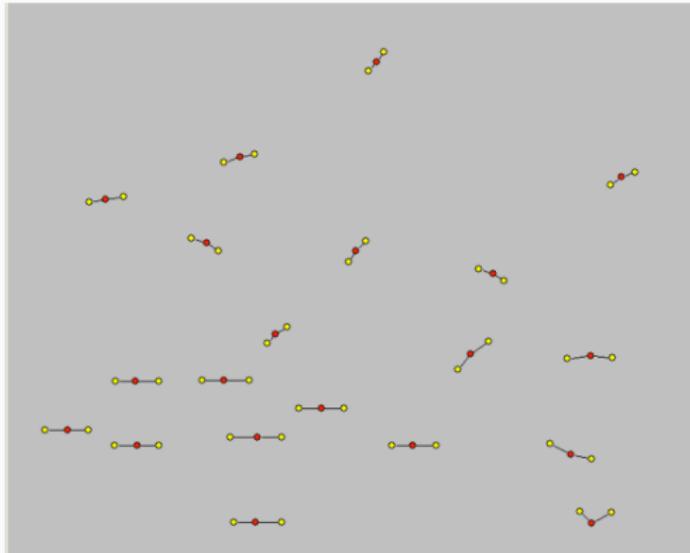


## Levels of Analysis: Complete Population

- Complete or Global Networks
  - The collection or relationships among all members of a population
- Measures:
  - Ego Network (collection of all egos/respondents)
  - Centrality
  - Sub-groups (sometimes called clusters or communities)
  - Equivalence (and other issues of role)

# Levels of Analysis: Why do levels matter?

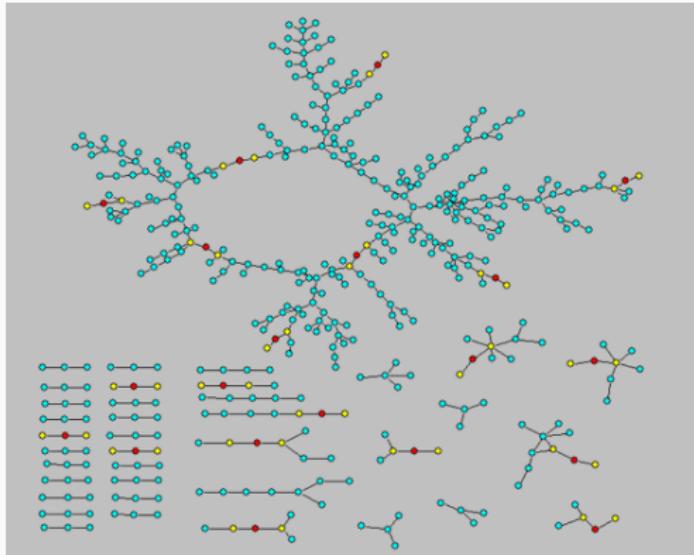
Who's at greatest risk of contracting an STI?



Bearman PS, Moody J, Stovel K. Chains of affection: The structure of adolescent romantic and sexual networks. American Journal of Sociology 2004;110(1):44-9

# Levels of Analysis: Why do levels matter?

Who's at greatest risk of contracting an STI?

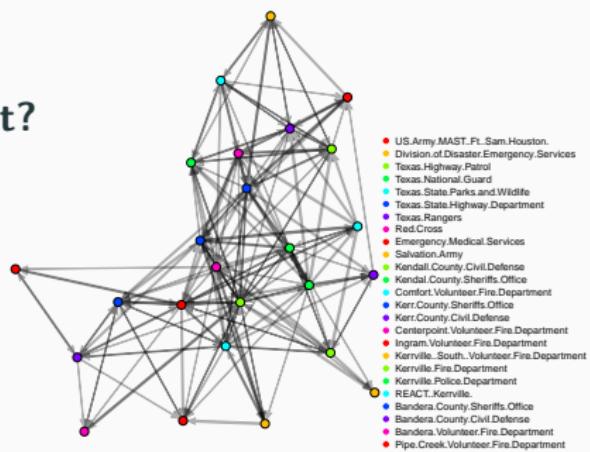


Bearman PS, Moody J, Stovel K. Chains of affection: The structure of adolescent romantic and sexual networks. American Journal of Sociology 2004;110(1):44-9

# Unit of Analysis: Measurement Issues

- Measurement issues can occur at varying levels
  - Nodes/Vertices/Actors
  - Ties/Relationships/Edges
  - (small) Groups
  - Complete Networks

**Who/What is Important?**



# Theoretical Frameworks: Common Metaphors

## “Pipes” – A Connectionist Metaphor

- Networks provide potential pathways through which various “bits” can be passed from one node to another via the links between them, e.g.:
  - Diffusion of information
  - Spread of an infectious disease
  - Traffic flows
  - VoIP
- Analyzing networks therefore aims to identify properties that will **promote** or **constrain** the potential transmission of those bits through the population
  - Node-level (trust)
  - Dyad-level (respect, distance, status difference, etc.)
  - Network-level (centrality, clustering, timing, etc.)

# Theoretical Frameworks: Common Metaphors

## “Pipes” – A Connectionist Metaphor

- A fun game! to Illustrate the ideas

adams, jimi. EPIC - SNA, 2017. Columbia University.

# Theoretical Frameworks: Common Metaphors

## “Prisms” - A Topological Metaphor

- Network patterns reveal **differences** or **similarities** in **status/role** comparisons
  - “equivalence” (e.g., relatives, employment hierarchies)
  - Identify groups
  - Identify advantageous individual positions
  - Role/identity construction – e.g., through shared memberships
- SNA in this case is interested in identifying patterns that can **differentiate** between varieties of **networks** or varieties of **locations** within networks
  - Equivalence
  - Cohesion
  - Clustering

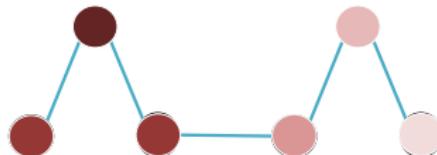
# Theoretical Frameworks: Common Metaphors

- Why might a pair of nodes be “similar”?
  - Pipes metaphor
    - Connectionist/Pathways
  - Prisms metaphor
    - Topological/Roles

adams, jimi. EPIC - SNA, 2017. Columbia University.

# Theoretical Frameworks: Common Metaphors

	Similarities	Variation
<b>Topology (Prisms)</b>	<b>Contextual shaping</b> e.g., position-based attitude development	<b>Structural capital</b> e.g., position-based power differentiation
<b>Connections (Pipes)</b>	<b>Contagion</b> e.g., disease flow	<b>Resource Access</b> e.g., differential access to information



adams, jimi. EPIC - SNA, 2017. Columbia University.

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# **Review of R and Discussion of Network Data in R**

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# Review of R

- Intro R Tutorial

## **References and Places for More Information**

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## References and Places for More Information i



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