# 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

# 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?

# 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?

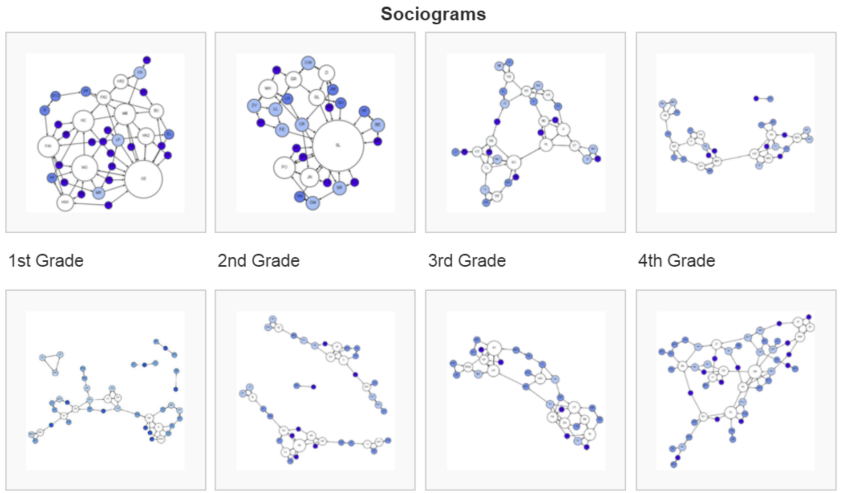
- A theory and a method for social scientific analysis that relies on:
  - *Structural* intuition
  - Systematic collection of *relational* data
  - Use of graphic *visualizations*
  - Mathematical or computational *models*

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.

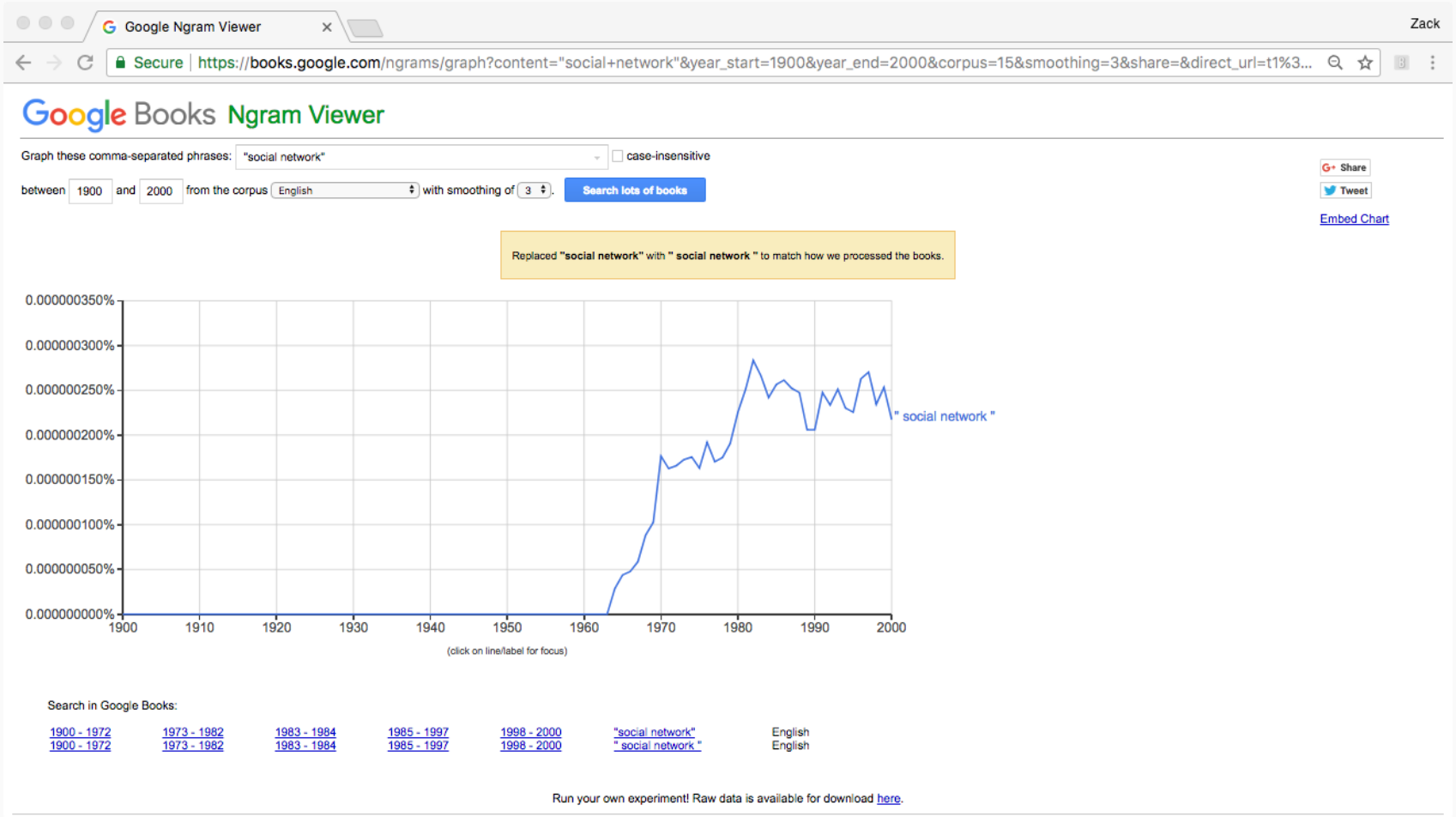




http://www.asgpp.org/docs/wss/wss.html

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

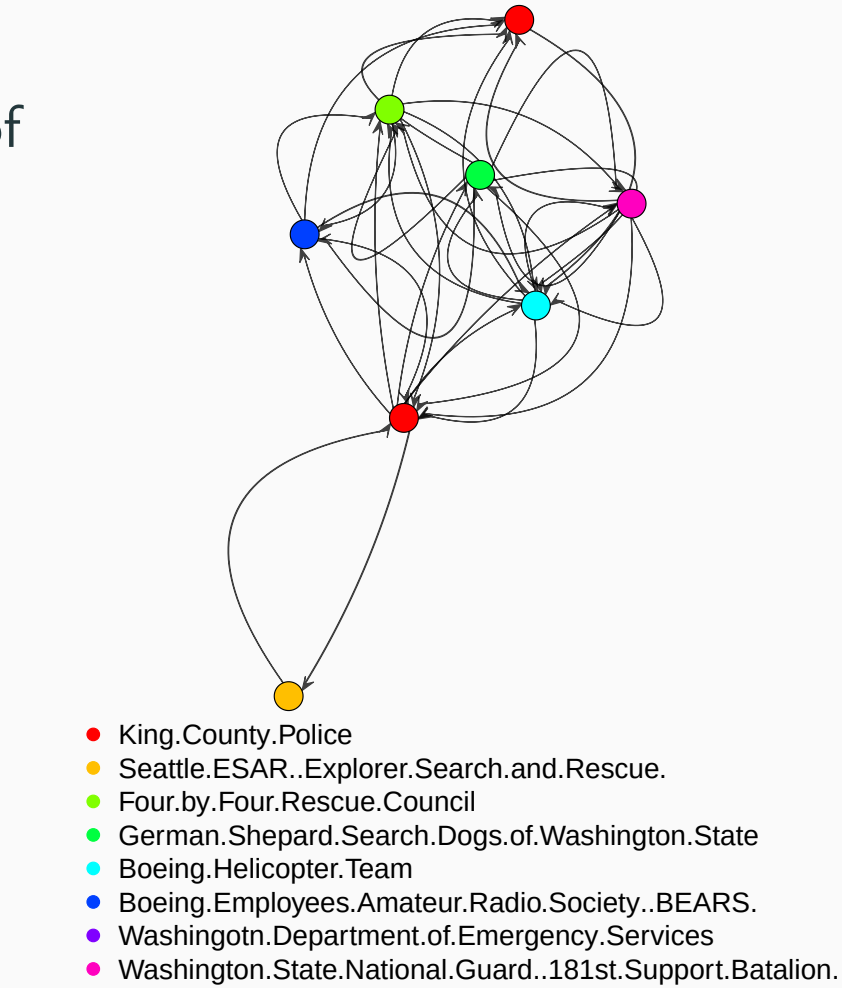
# What is Social Network Analysis?



# 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?

# Some Types of Networks

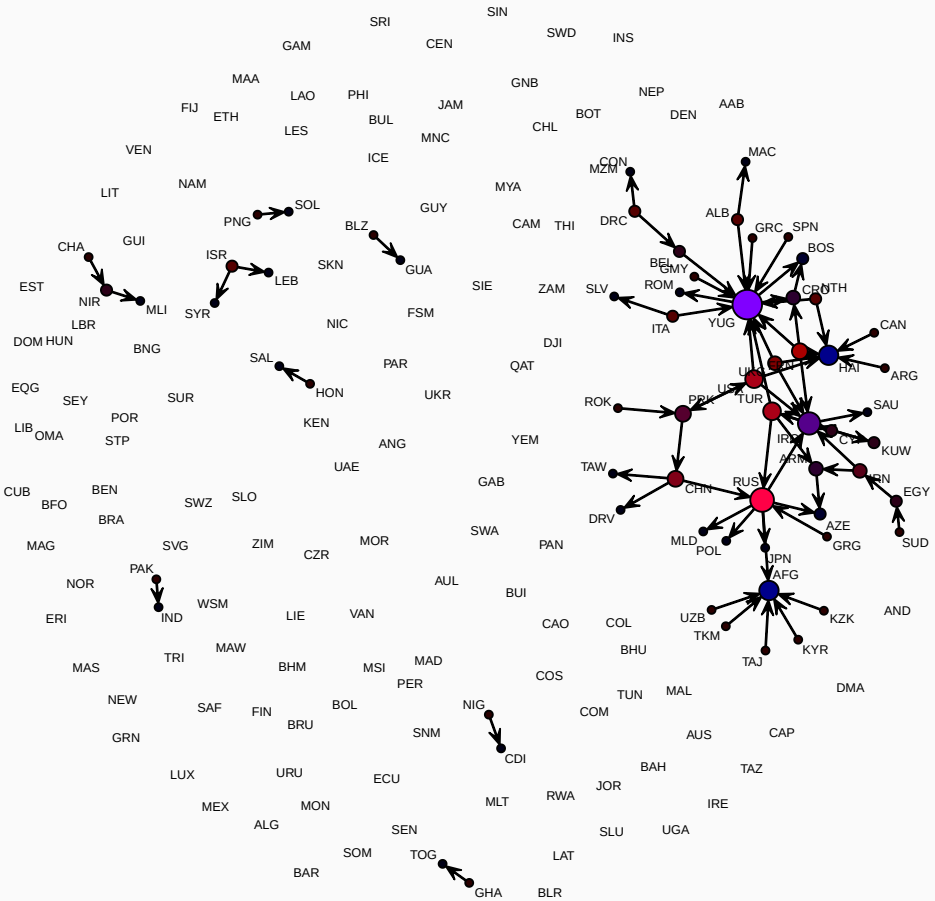
- Conceptual: shared or antithetic properties
  - E.g., similarity/difference in individual attributes, correlation among variables, inclusion/exclusion, surface matchings on proteins
- Co-categorical: shared membership
  - E.g., organizational co-membership, event co-participation, co-occurrence of words within texts
- Nominational: 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
- Behaviorial
  - 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. . .

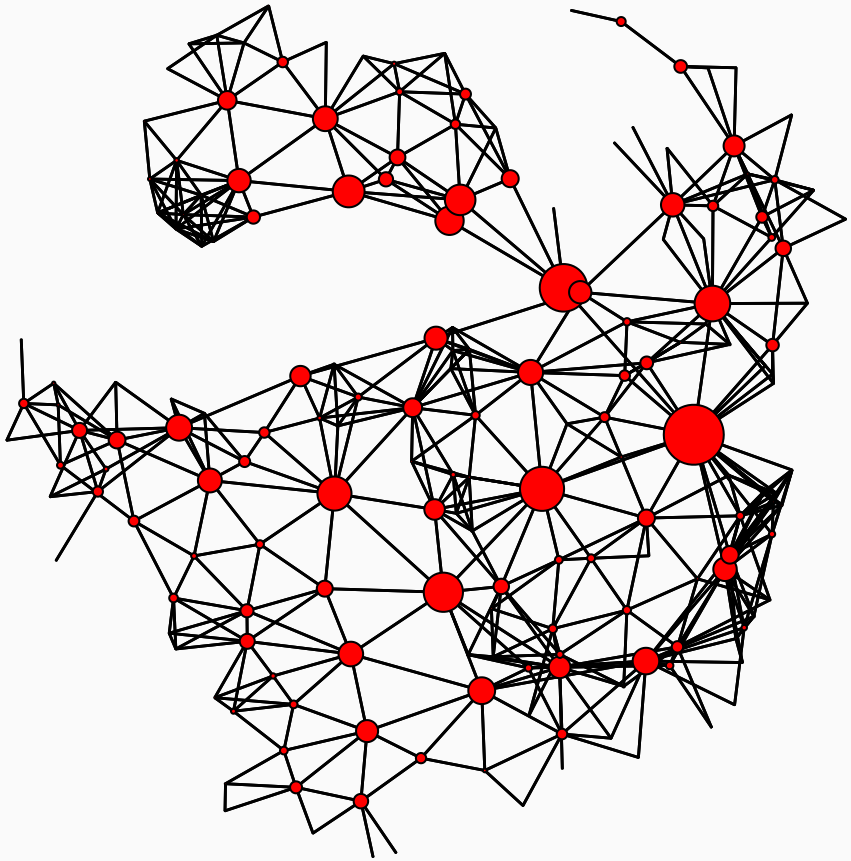
# Correlates of War Project: Militarized Interstate Disputes

**1993 militarized interstate disputes (MIDs)**

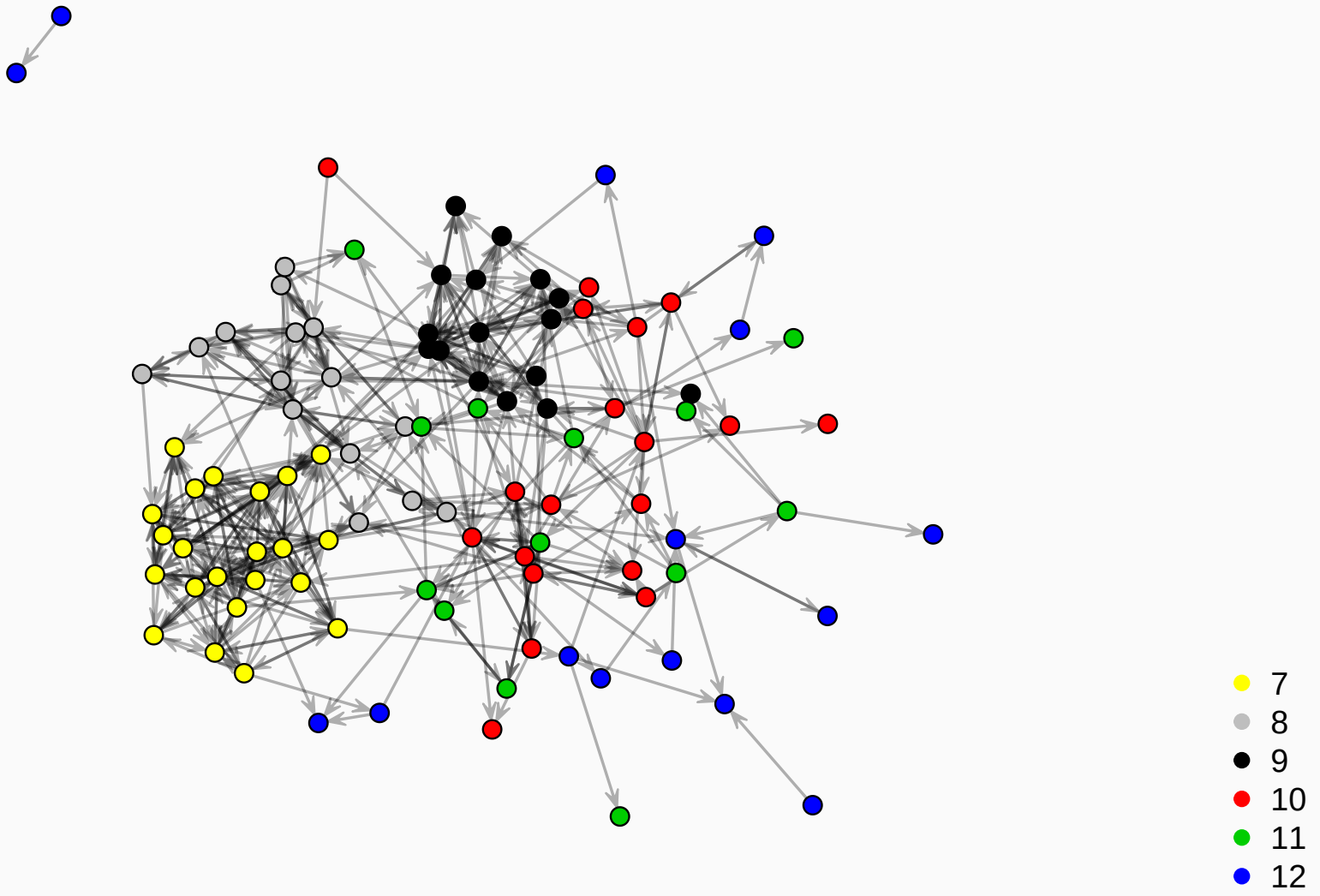


# Correlates of War Project: Contiguity Network

**Contiguity Network, 1993**

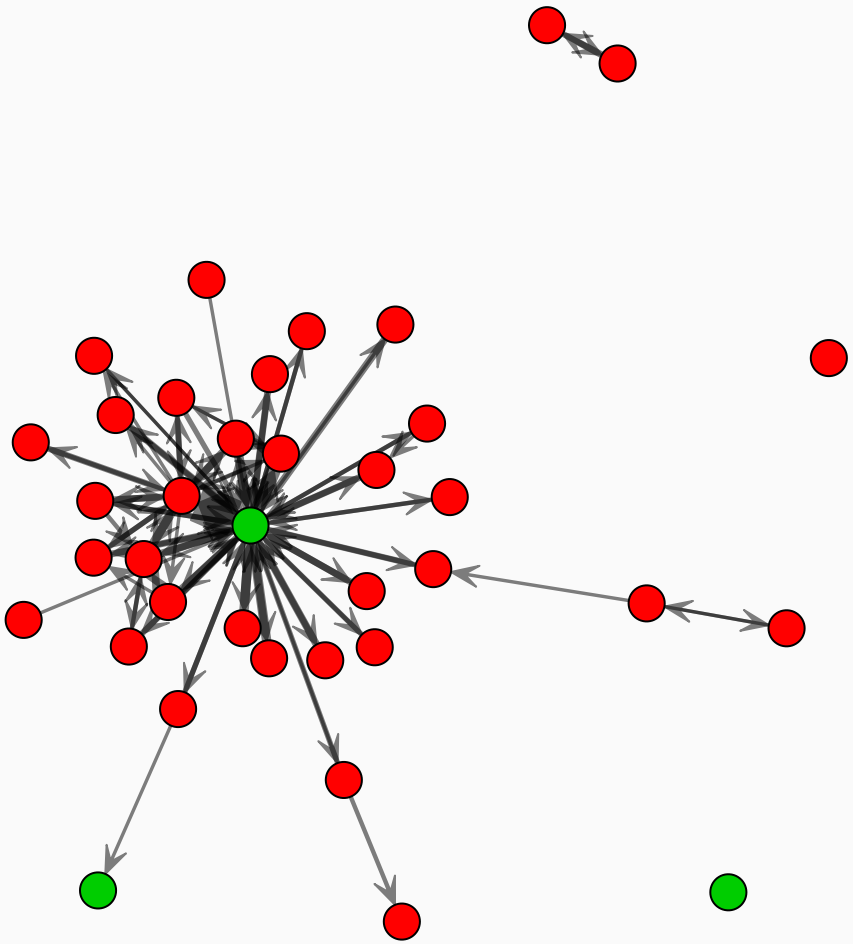


# Faux Desert High (Simulation of an Add Health HS)




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).

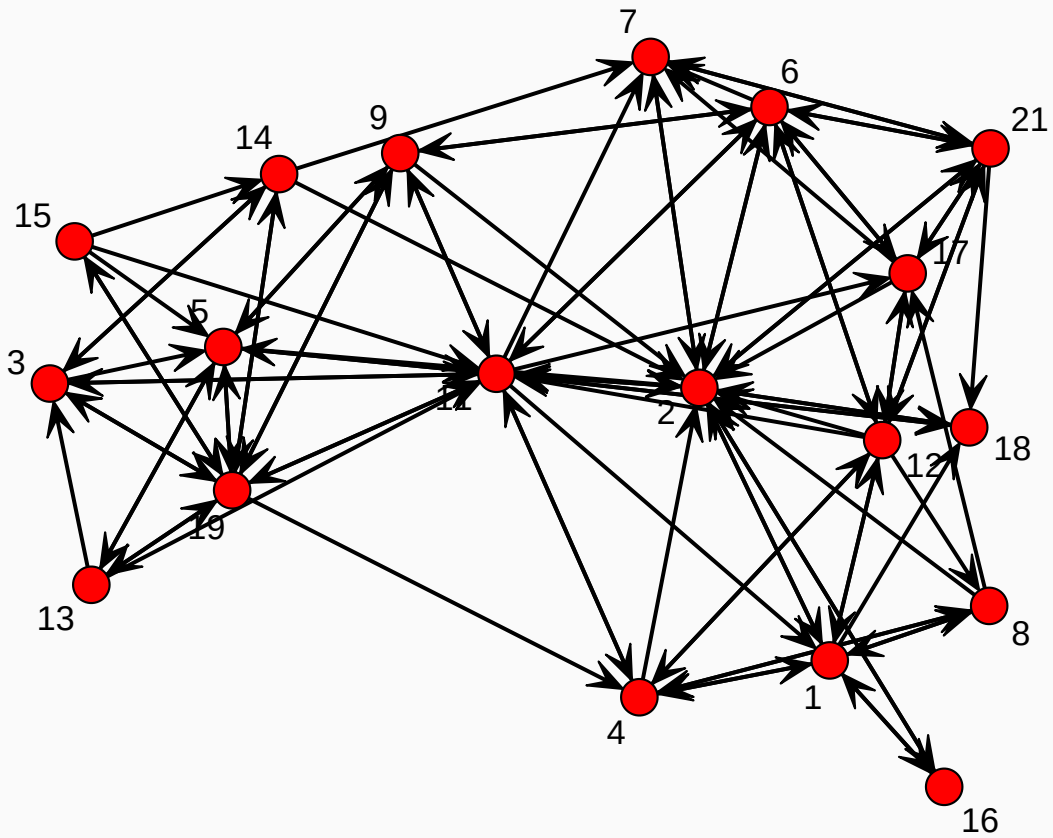
# World Trade Center Radio Communication




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.

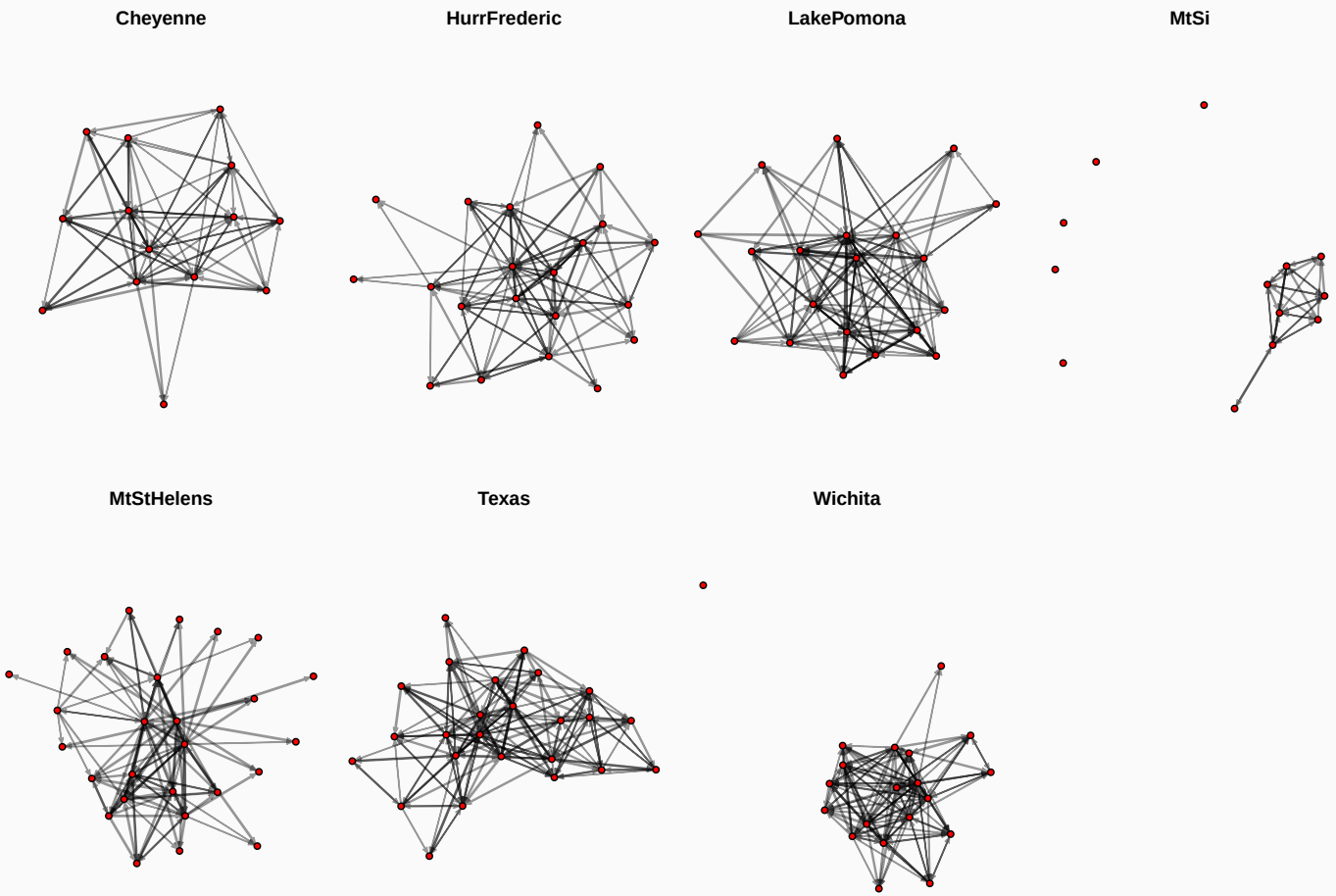
# David Krackhardt's Perceived Friendships

**Consensus Model of Perceived Friendships in an Organization**



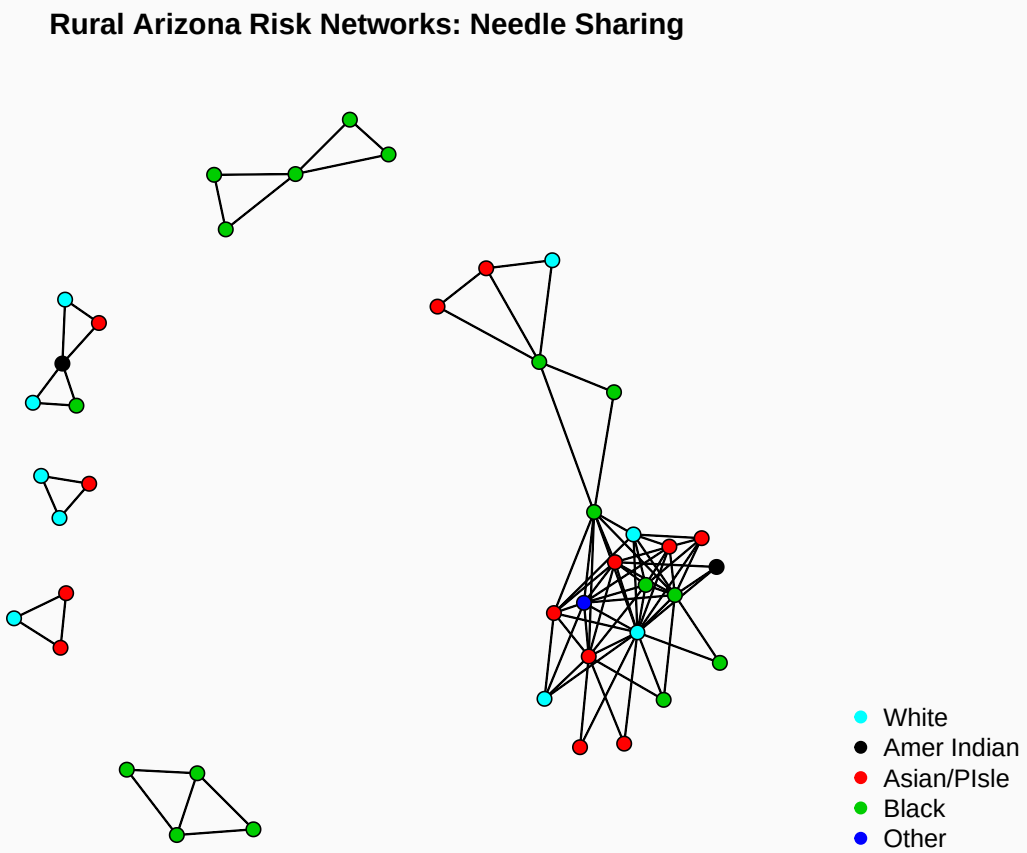

Krackhardt, D. (1987). Cognitive social structures. Social networks, 9(2), 109-134.

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



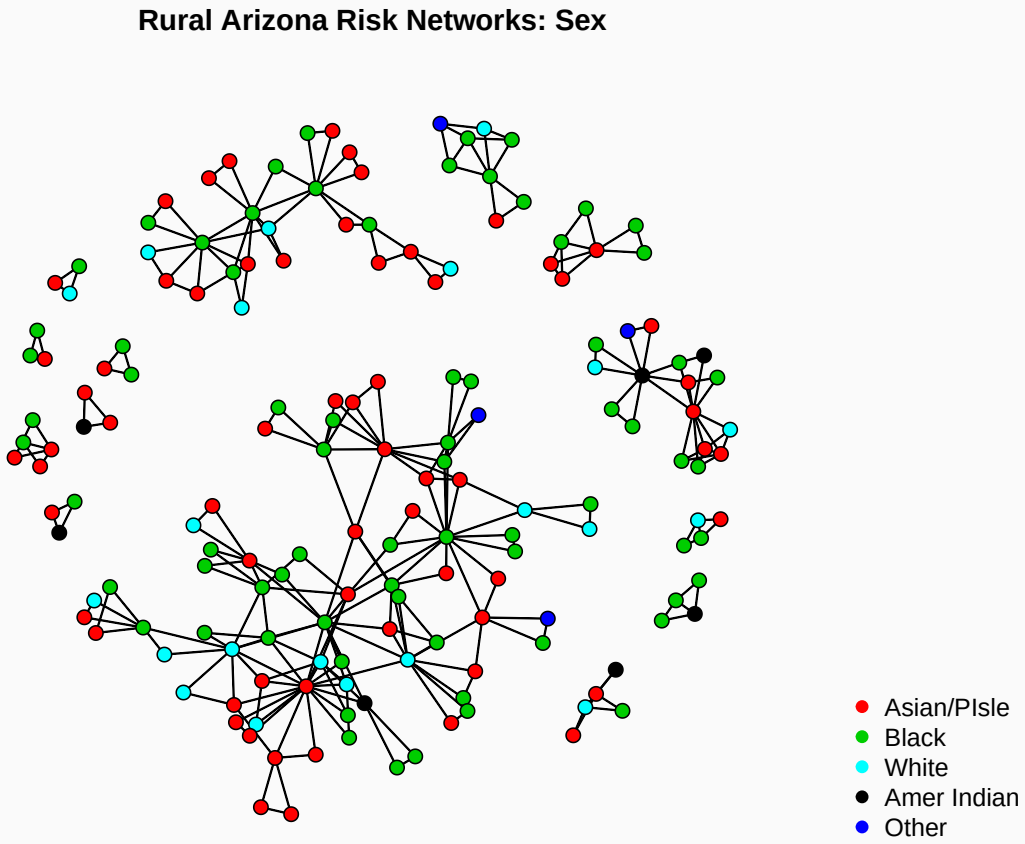

Marcum, C. S., Bevc, C. A., & Butts, C. T. (2012). Mechanisms of control in emergent interorganizational networks. Policy Studies Journal, 40(3), 516-546.

# Needle Network




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

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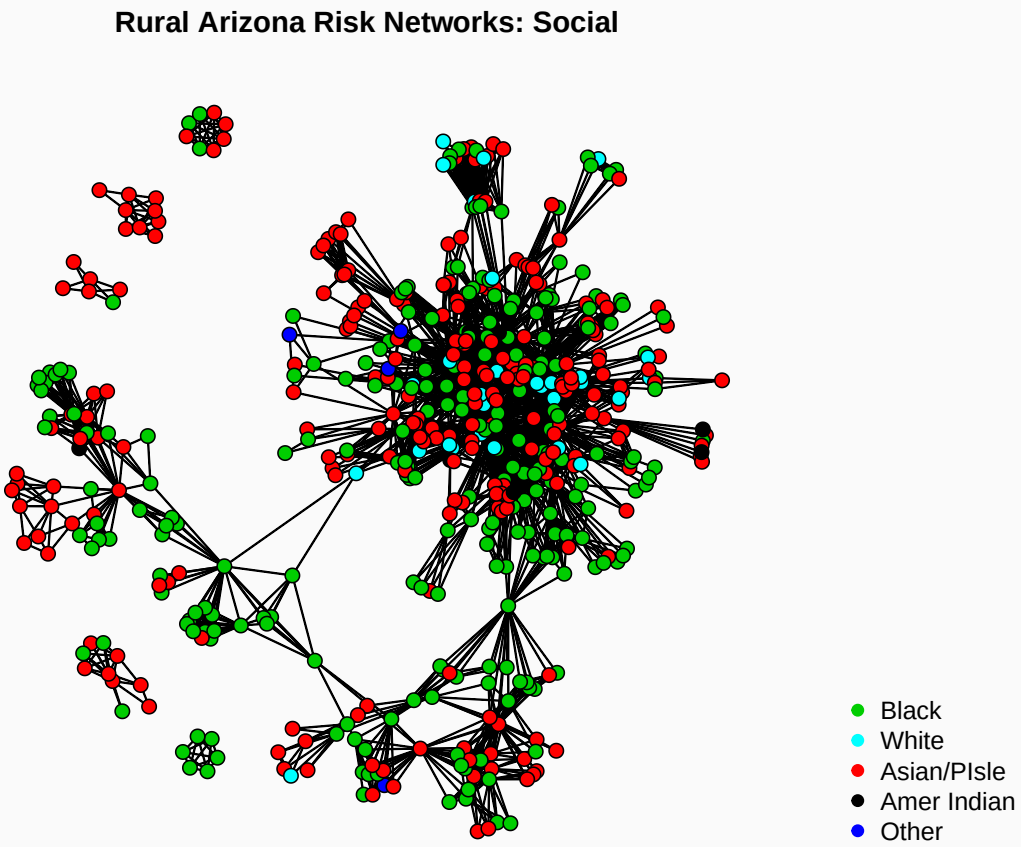
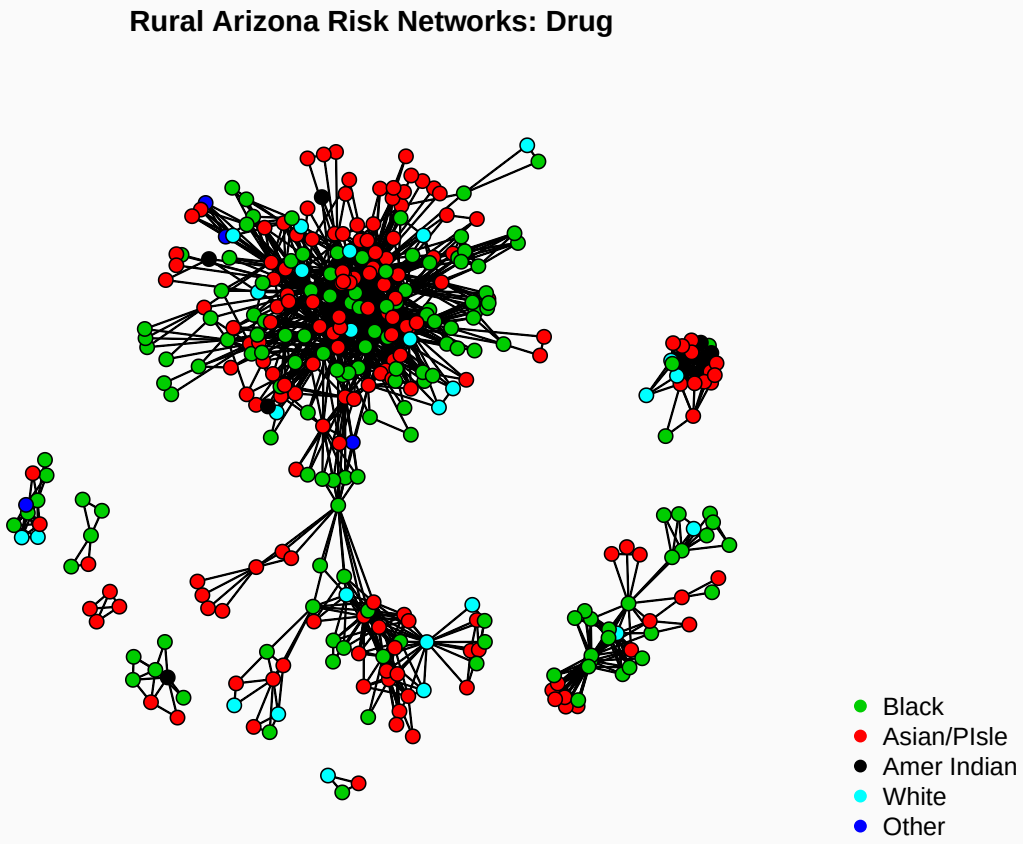
# Social Contact Network




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




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)

# Defining Terms: A Basis in Graph Theory

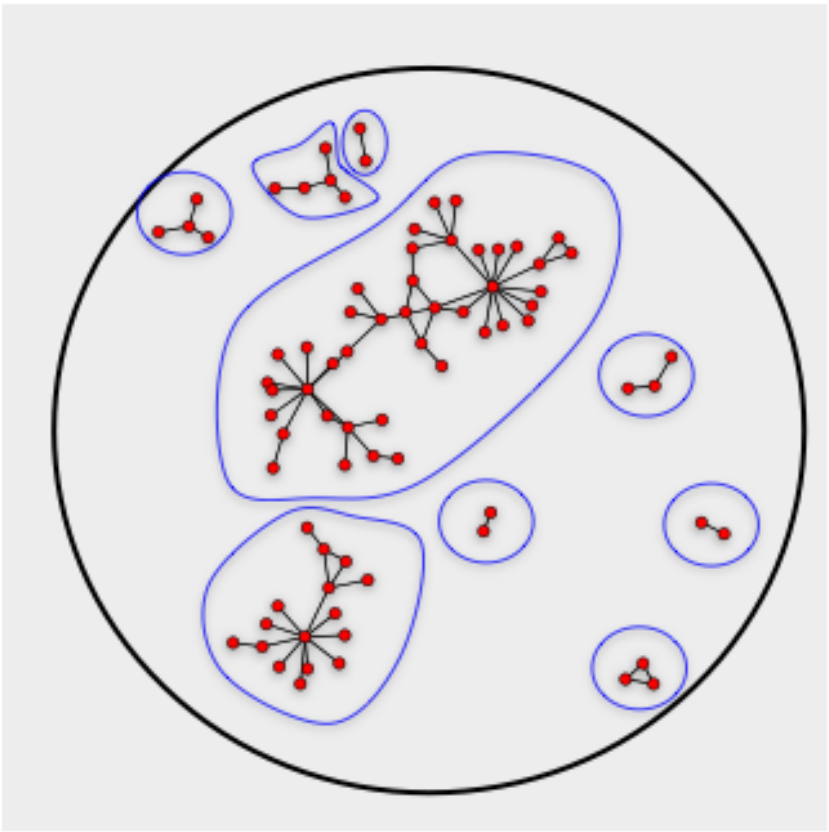
- Points (or nodes/vertices)
  - In social science – "actors"
    - People, organizations, nation-states, mobs, papers, ideas
  - In other settings – "entities"
    - Animals, locations, objects
- Lines (or ties/relations) – interaction b/t nodes
  - These can be directed (arcs), non-directed (edges) 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

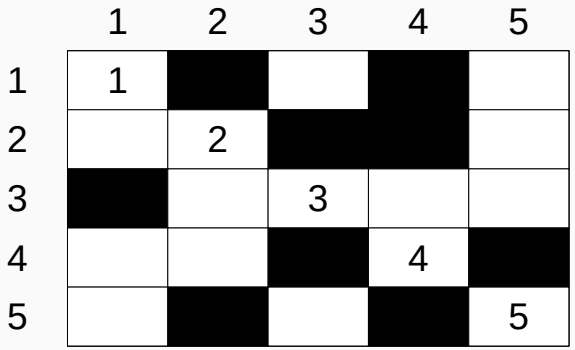
- Aggregate of ALL nodes AND ties for entire population in a single representation
  - directed (digraph) or un-directed (graph)
  - Can be dissected into a variety of subgraphs
- Mathematical notation, $G = (V, E)$

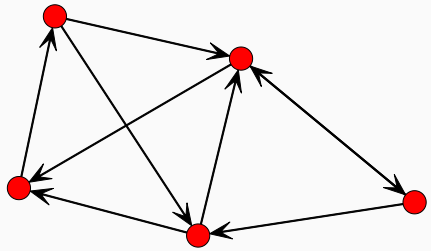


Borgatti, SP. 1994. "A Quorum of Graph Theoretic Concepts." Connections 17:47-49.

# 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 |



- 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**

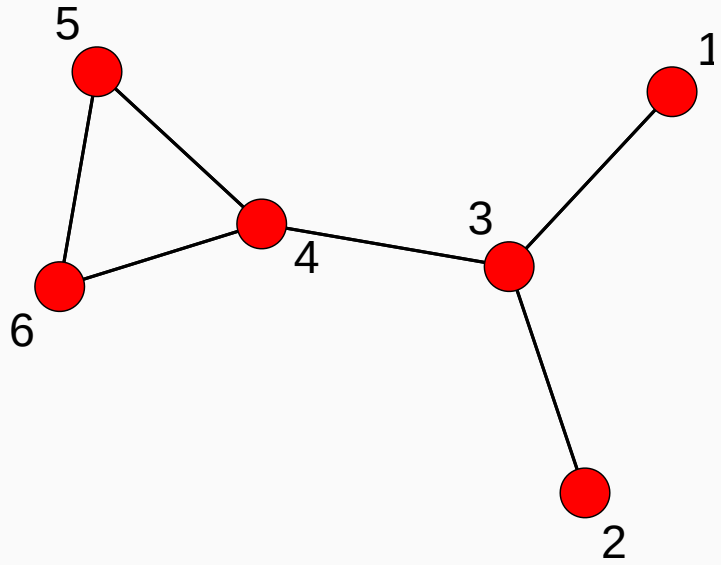
| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | | 0 | 1 | 0 | 0 | 0 |
| 2 | 0 | | 1 | 0 | 0 | 0 |
| 3 | 1 | 1 | | 1 | 0 | 0 |
| 4 | 0 | 0 | 1 | | 1 | 1 |
| 5 | 0 | 0 | 0 | 1 | | 1 |
| 6 | 0 | 0 | 0 | 1 | 1 | |

- 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**




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

# 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 | |

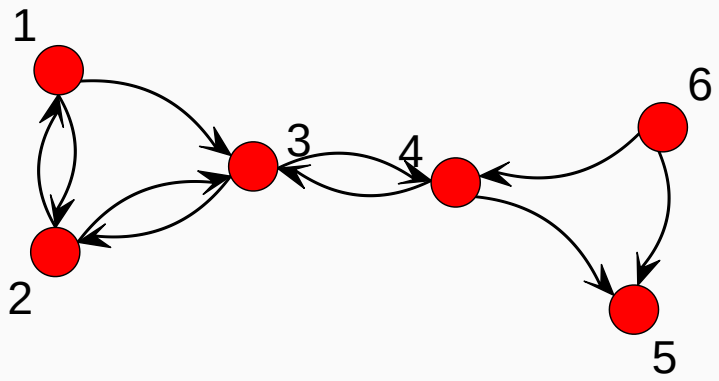
**Friendship Nomination**

**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**




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

# 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 | |

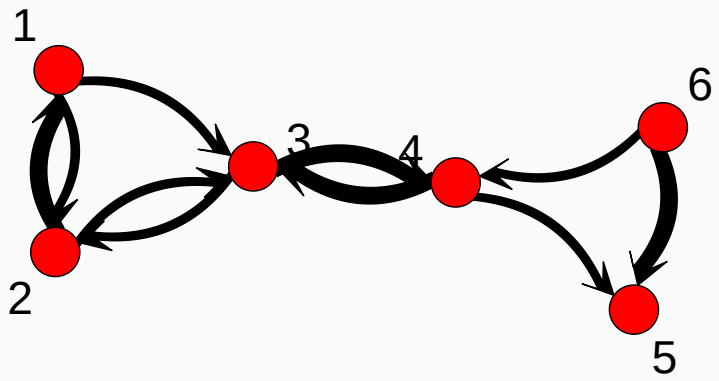
**Friendship Nomination**

**Weighted Edge List (Arc List)**

| snd | 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**




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

# Relational Data

**Friendship Nomination**

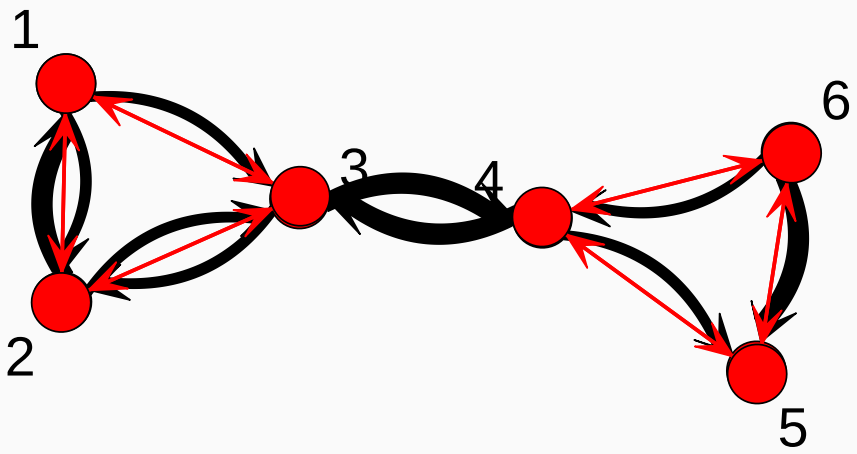
**Adjacency Matrix (Weighted)**

| | 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**

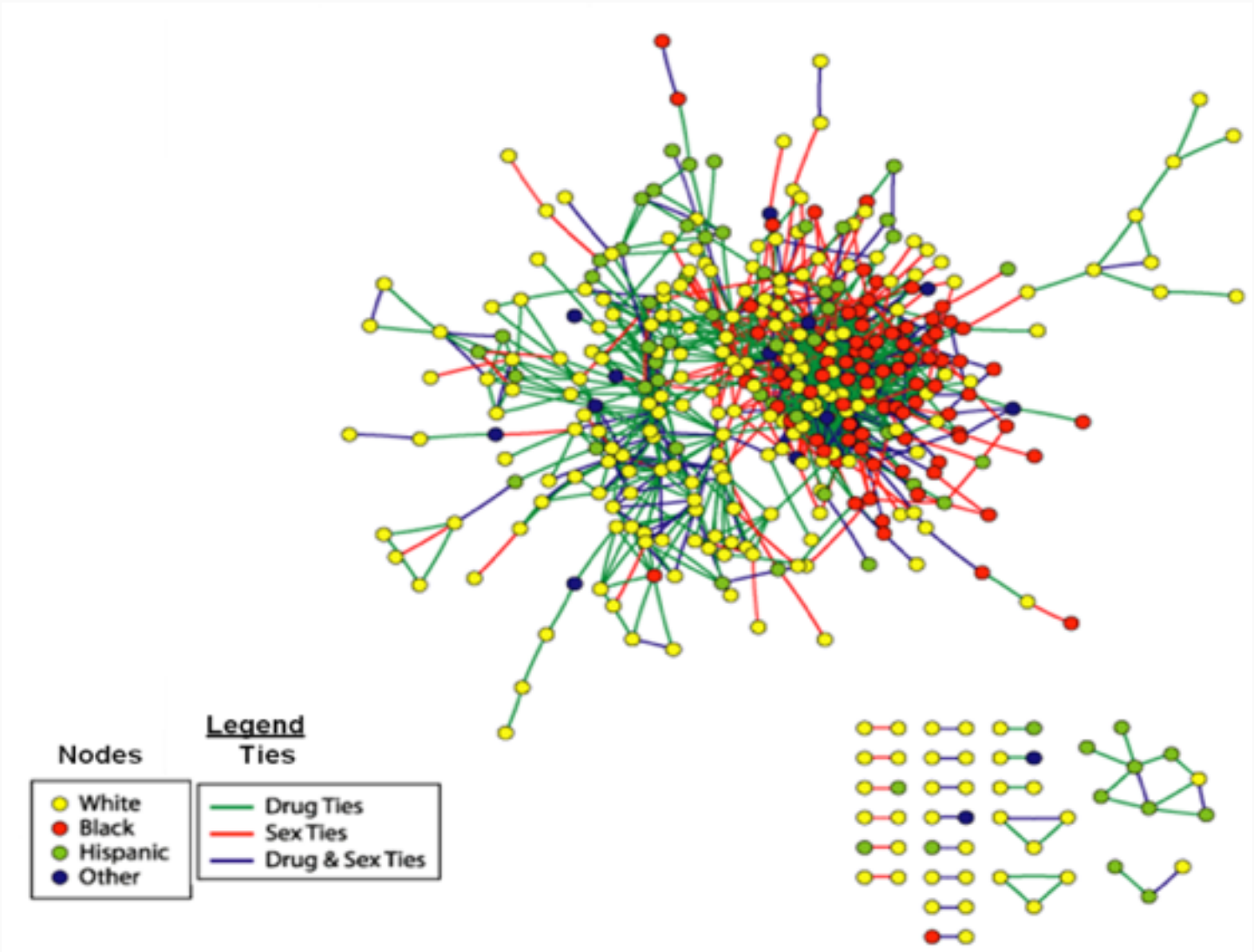
| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1 | | 1 | 1 | 0 | 0 | 0 |
| 2 | 1 | | 1 | 0 | 0 | 0 |
| 3 | 1 | 1 | | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | | 1 | 1 |
| 5 | 0 | 0 | 0 | 1 | | 1 |
| 6 | 0 | 0 | 0 | 1 | 1 | |

**Friendship Nomination**



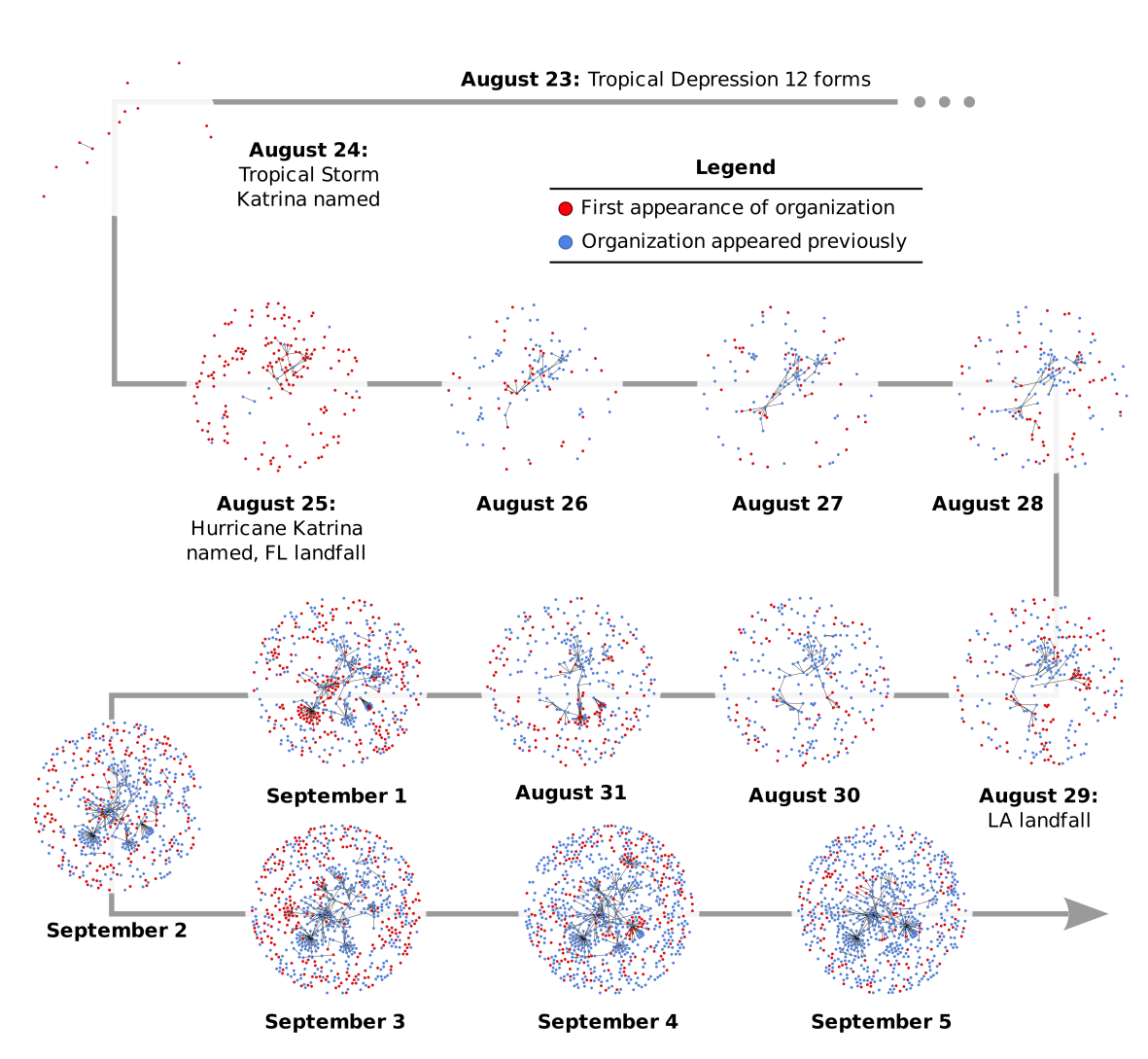

Knoke D, Yang S. Social Network Analysis: Sage; 2007.

# 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., | e.g., |
| e.g., | e.g., | e.g., | e.g., | e.g., | e.g., | e.g., | Sex with | Information |
| Same spatial and temporal space | Same clubs | Same gender | Mother of | Friend of | Likes | Knows | Talked to | Beliefs |
| | Same events | Same attitude | Sibling of | Boss of | Hates | Knows about | Advice to | Personnel |
| | etc. | etc. | | Student of | etc. | | Helped | Resources |
| | | | | Competitor of | | Sees as happy | Harmed | etc. |
| | | | | | | etc. | 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 |

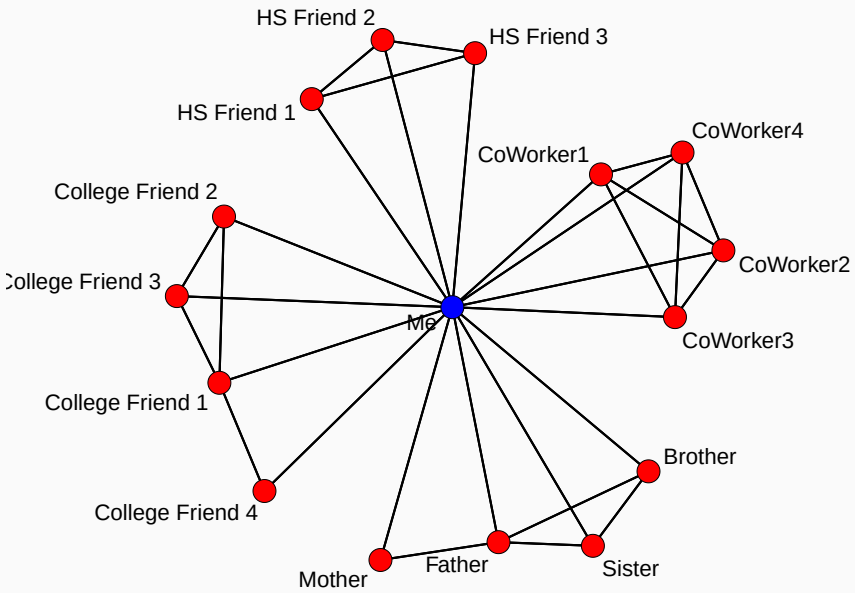
# Frameworks (Orientation)

- Methodological Aims
- Level of Analysis
- Unit of Analysis
- Theoretical Modtivations
    - 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

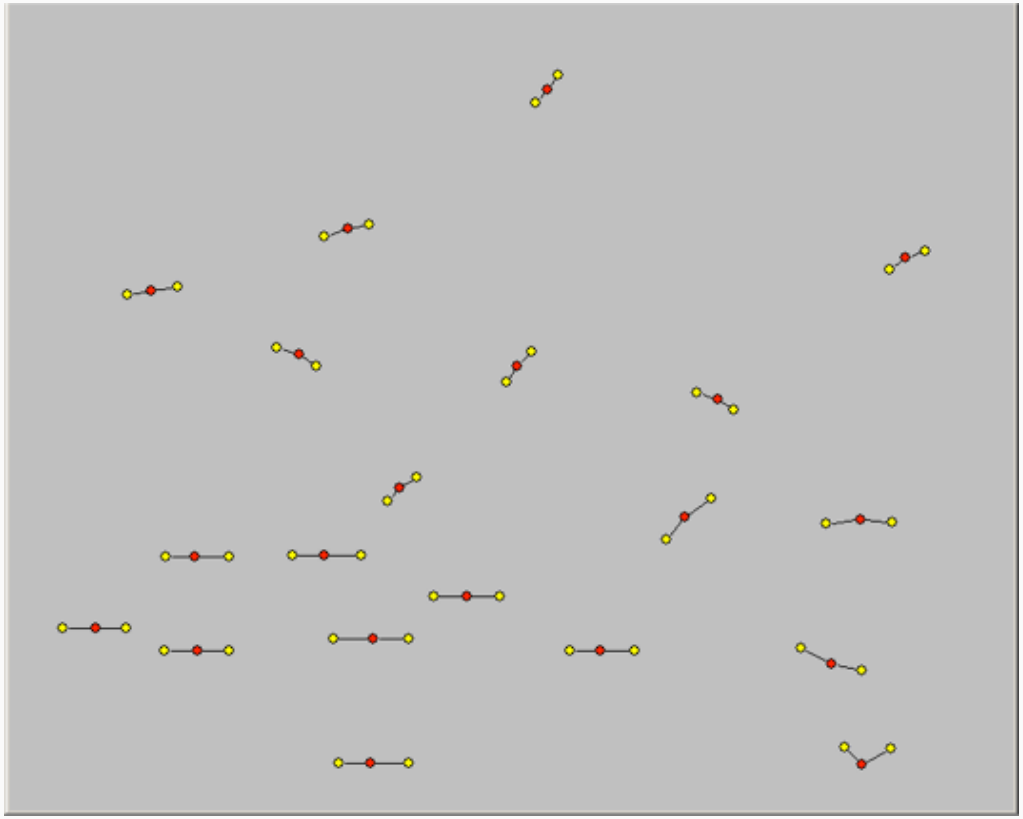


# Levels of Analysis: Complete Population

- 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 orther issues of role)

# Levels of Analysis: Why do levels matter?

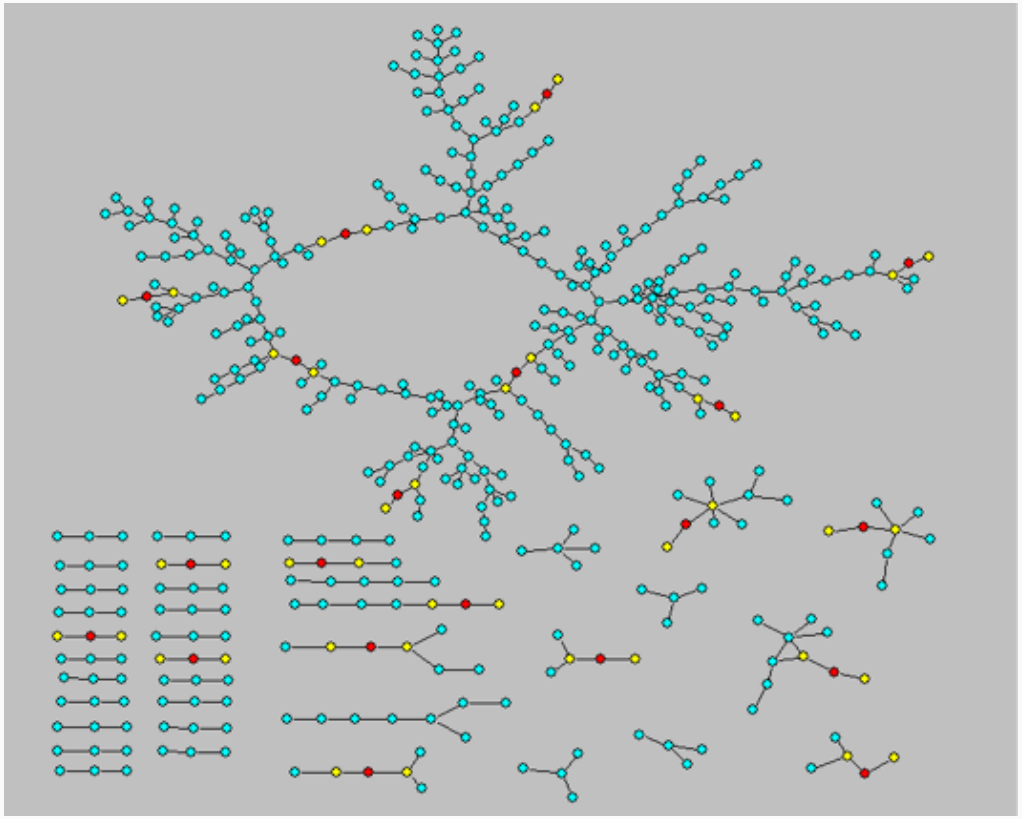
## Who's at greatest risk of contracting an STI?



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?

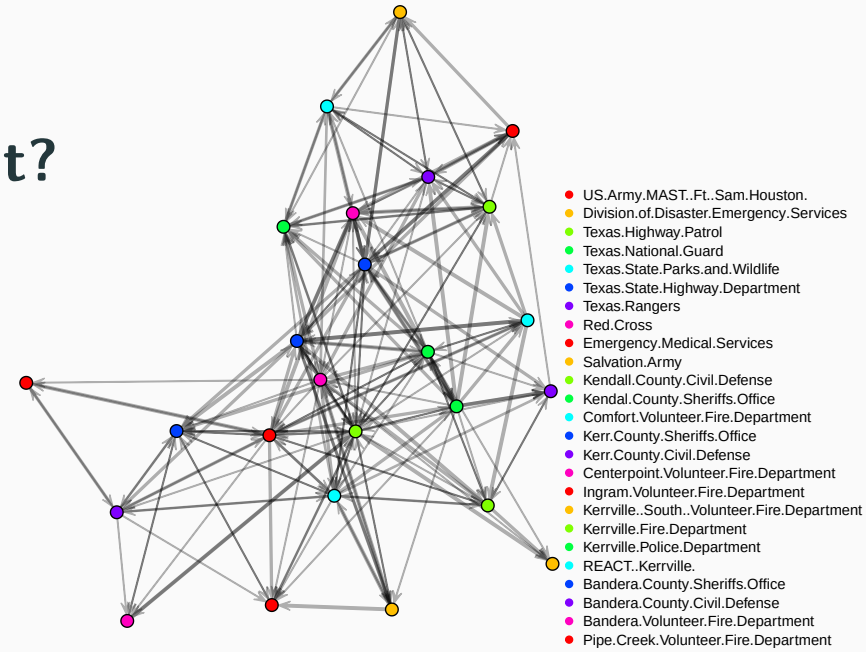


Bearman PS, Moody J, Stovel K. Chains of affection: The structure of adolescent romantic and sexual networks. American Journal of Sociology 2004;110(1):44-9

# Unit of Analysis: Measurement Issues

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

**Who/What is Important?**




Texas

# 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

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# Theoretical Frameworks: Common Metaphors

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

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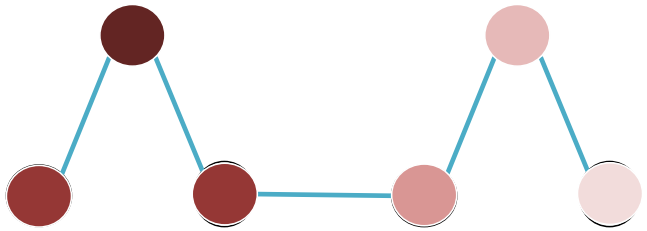
# Theoretical Frameworks: Common Metaphors

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



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# 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

# Review of R and Discussion of Network Data in R

# Review of R

- Intro R Tutorial

# References and Places for More Information

# References and Places for More Information i

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