The Basics of Networks

CRJ 523

Network Criminology

Goal: Answer some questions

- What do networks “look like”?
- How do we collect network data?
- What does network data “look like”?
- How do we analyze network data?

Network Science

- Network **science** is an approach to science that views the world as being composed of systems of actors connected through relational ties (i.e. a **network**).
- The *explanan* and *explanadum* is network **structure**.
  - How does the network matter?
  - What influences the network?

Network Analysis

- Network **analysis** is the set of tools used to study *structural variables*.
  - A set of *relational* methods for systematically understanding and identifying connections among actors.

Basic Data Elements

What do networks "look like"?

Basic Data Elements

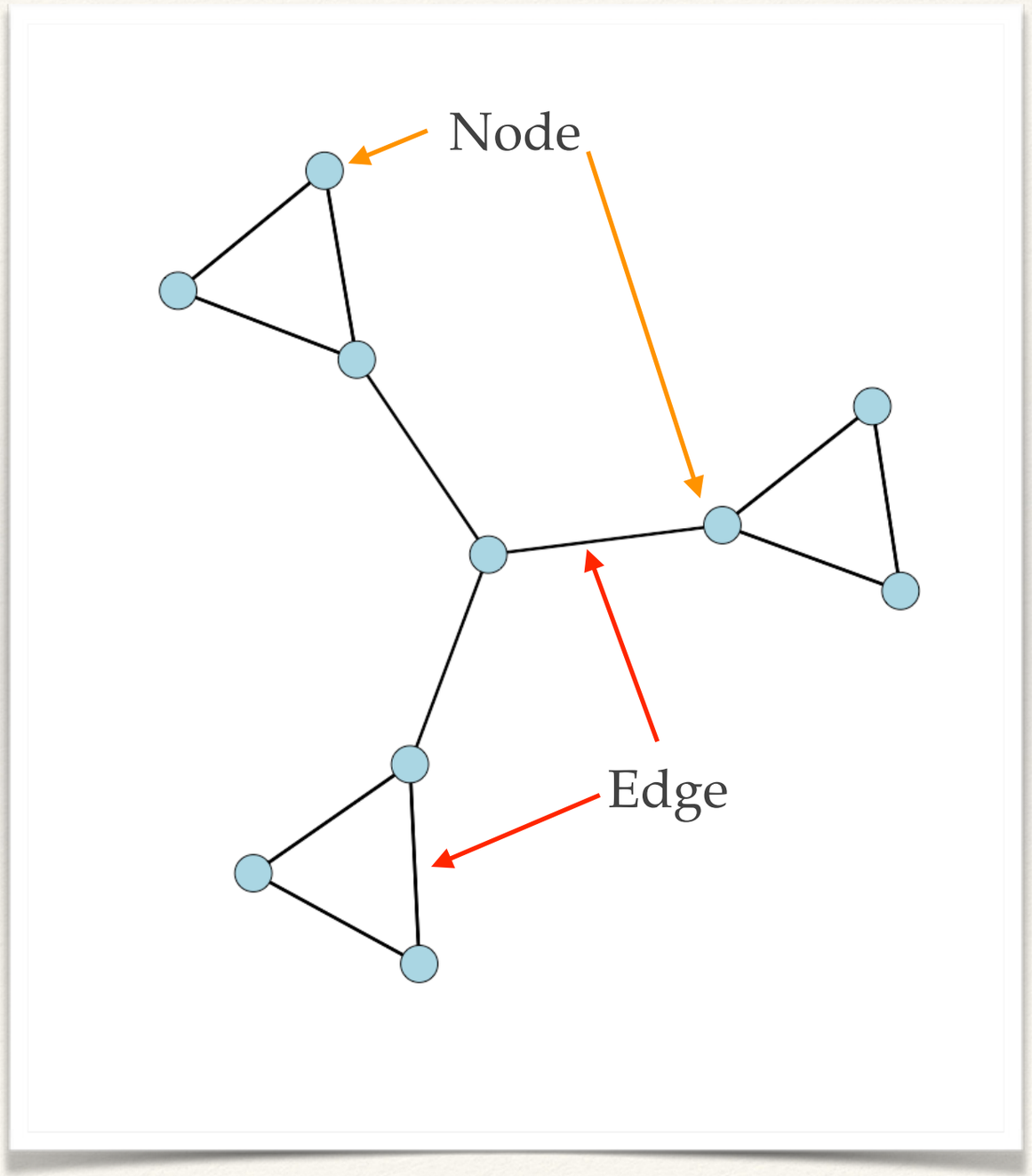
- Network (relational) data represent:
  - **Connections** (aka ties, arcs, edges, lines, ties) among,
  - **Entities** (aka nodes, vertices, actors, points, dots).
- I will use *node* to mean **entities** and *edge* to mean **connections.**

Basic Data Elements

- A *node* can be anything that can link to something else.
- An *edge* can be anything that can record a connection between nodes.
  - *What are some **nodes** and **edges** that come to mind?*

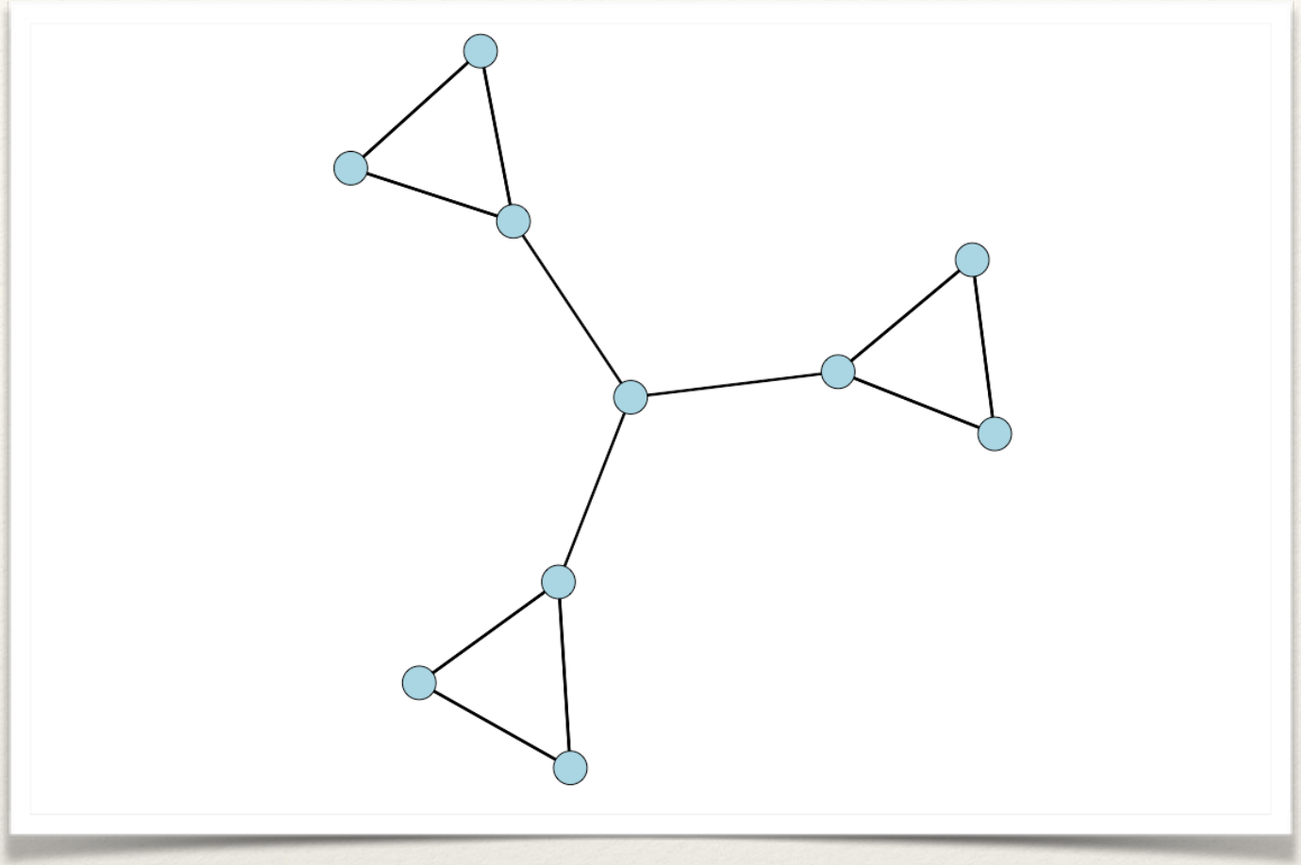
Basic Data Elements

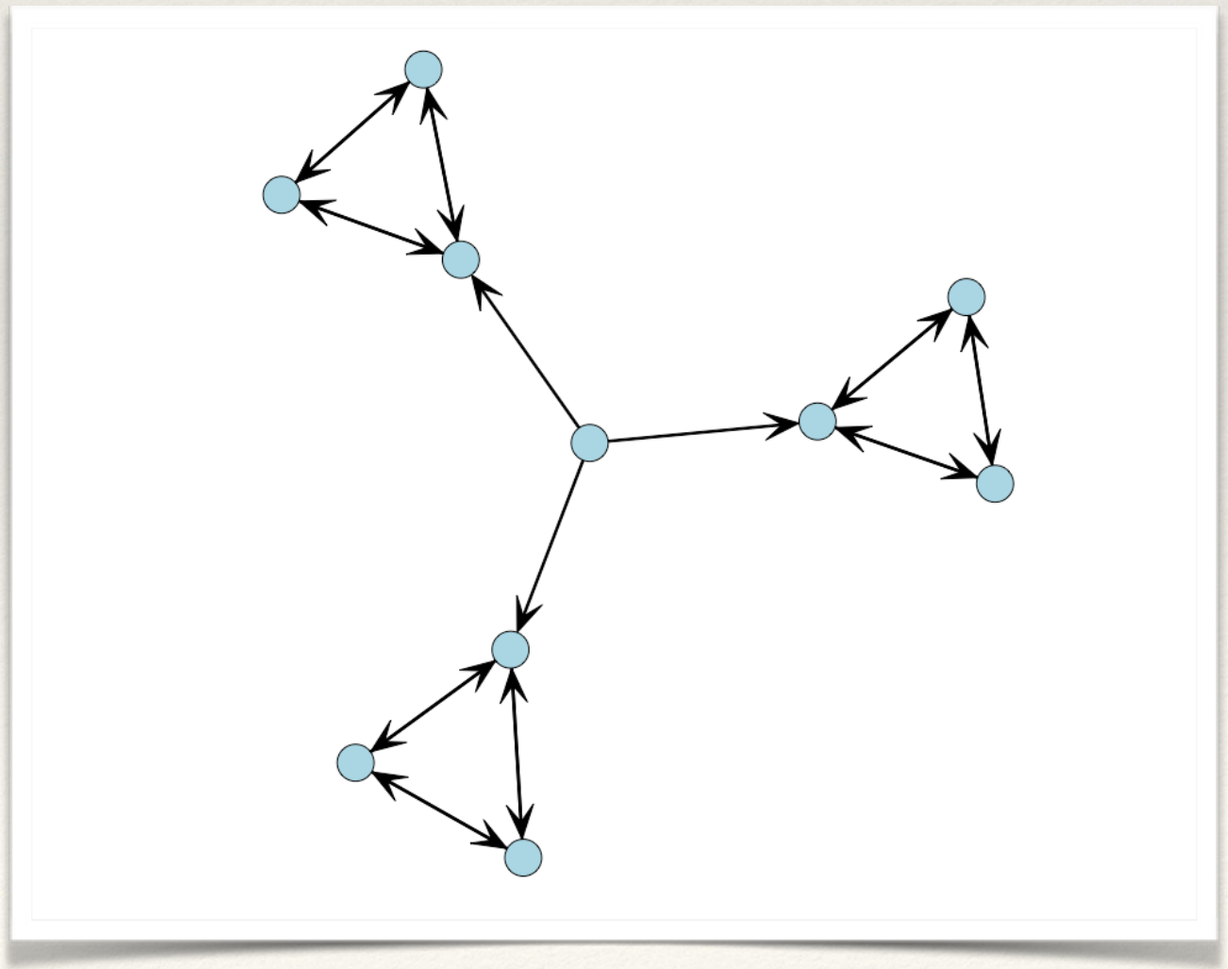
- On a graph, nodes are represented by *points* and edges are represented by *lines*.

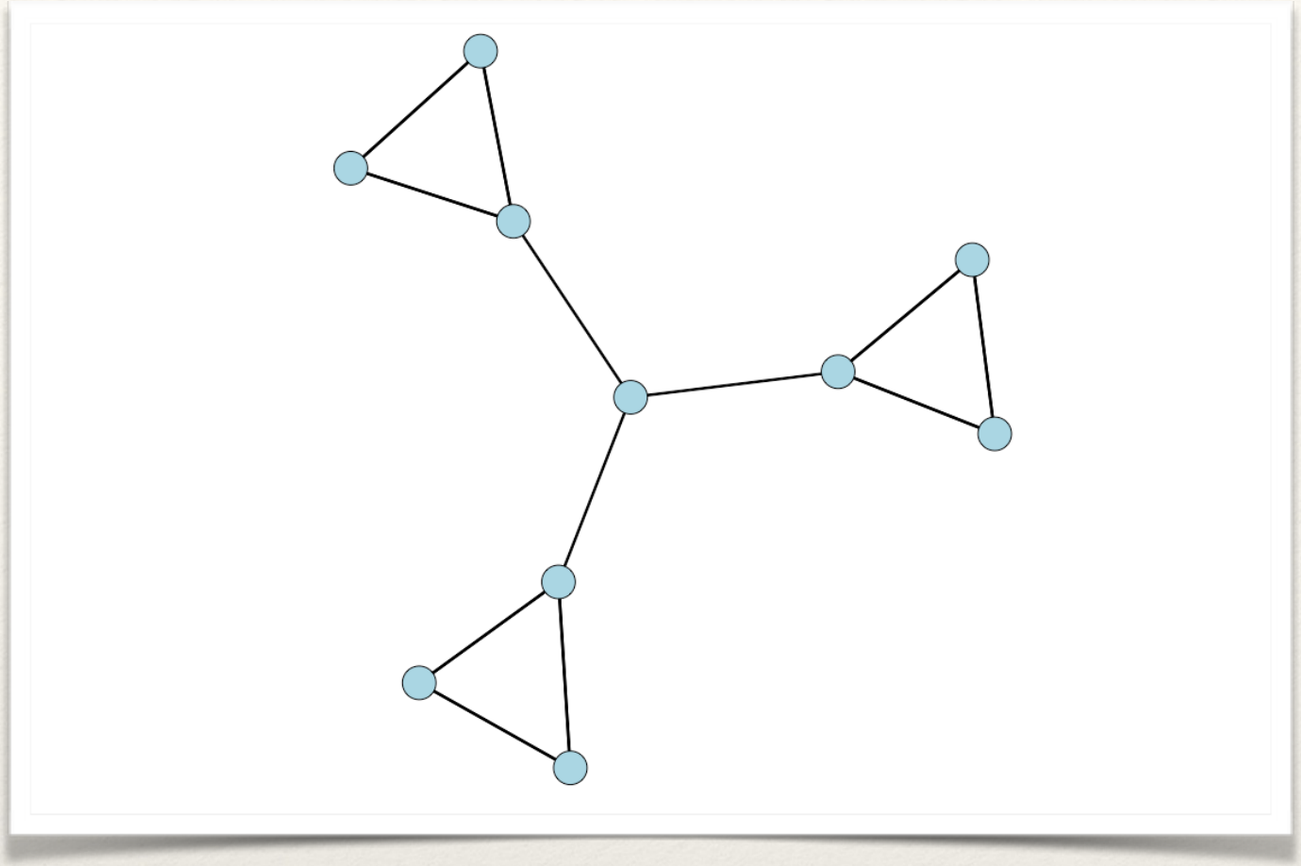


Basic Data Elements

- Edges can be:
  - Directed or Undirected.

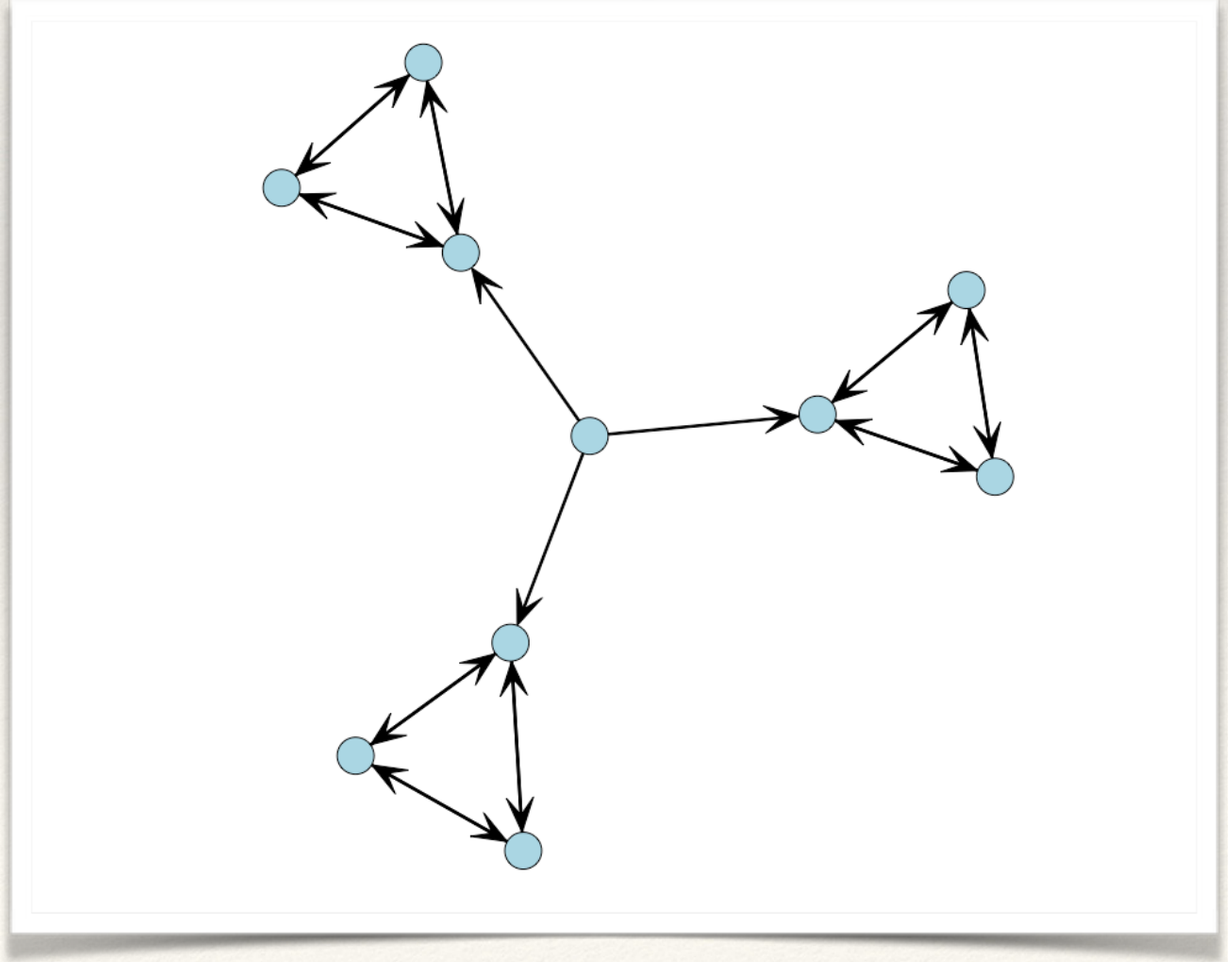






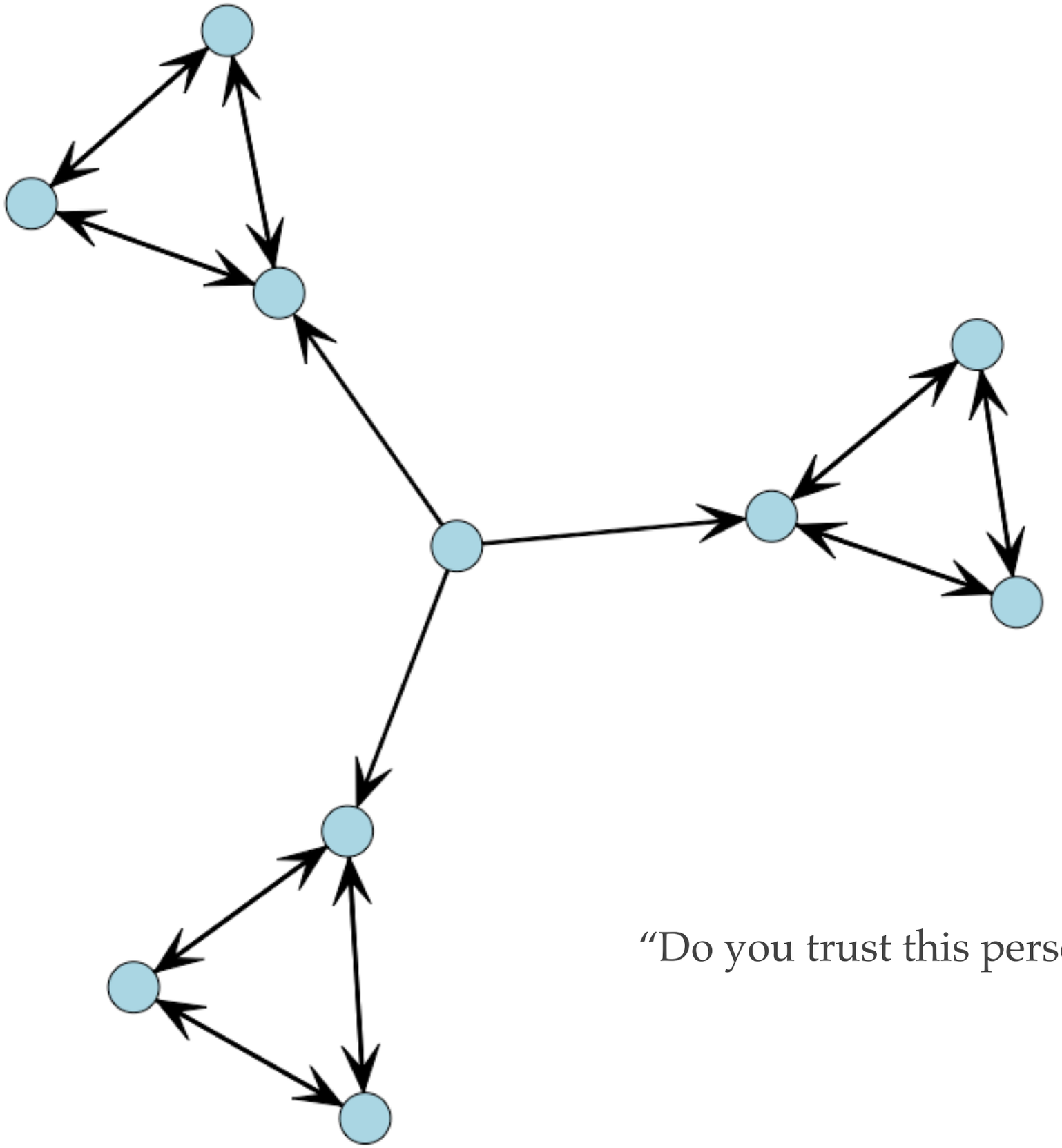
Suppose the edges measure communication…

How are these structures different?

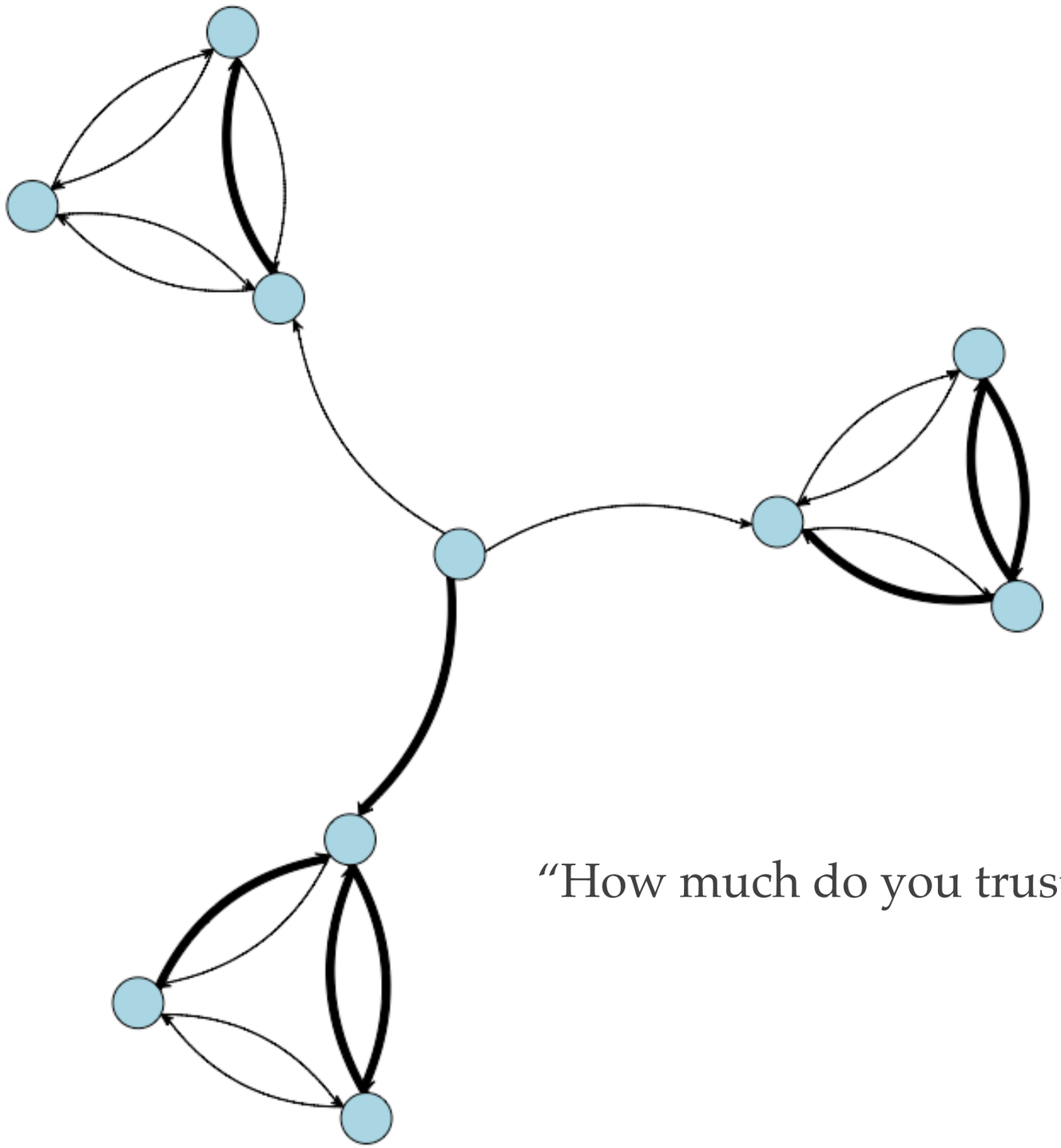


Basic Data Elements

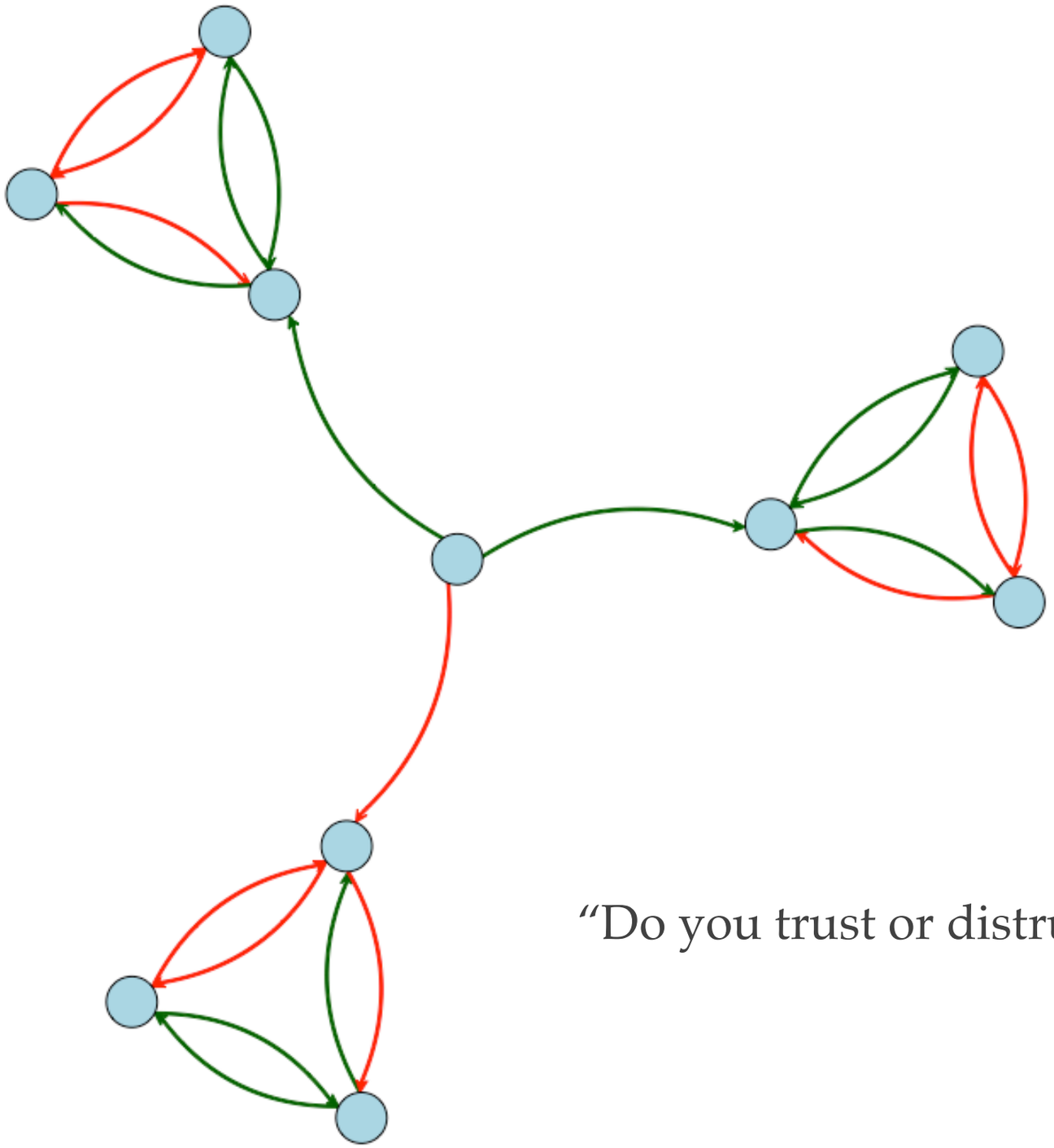
- **Edges** can be:
  - Binary (0/1; present/absent); Valued (0/1/2…); Signed (+/-).



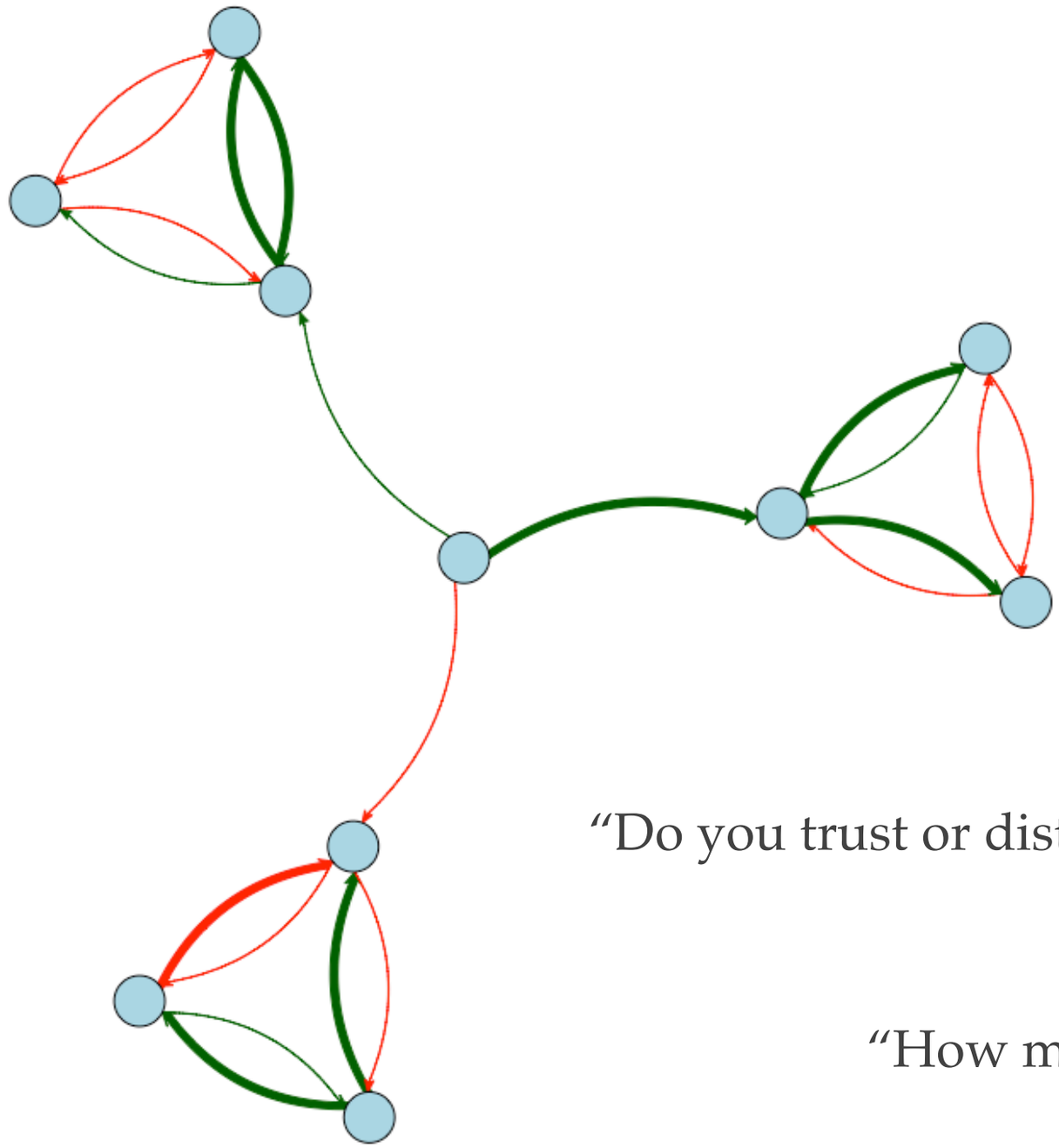
"Do you trust this person?"



"How much do you trust this person?"



"Do you trust or distrust this person?"



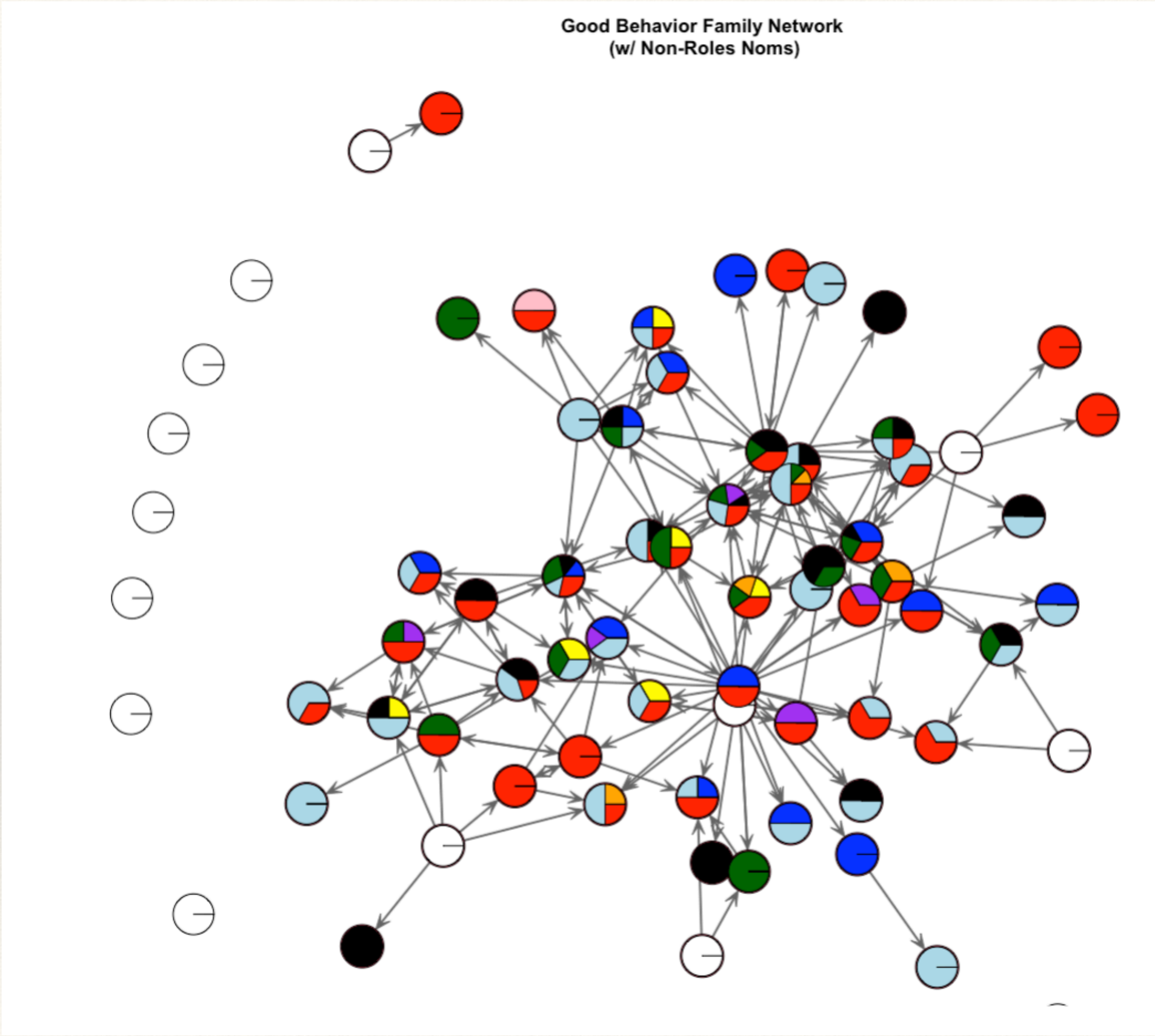
"Do you trust or distrust this person?"

"How much?"

Basic Data Elements

- **Edges** can have different meanings and therefore be of different *types*.
  - Social relationships (sister, friend, likes, knows)
  - Interactions (has sex with, talks to, seeks advice from)
  - Flows (diseases, attitutes)

Family Role Nominations among Incarcerated Women



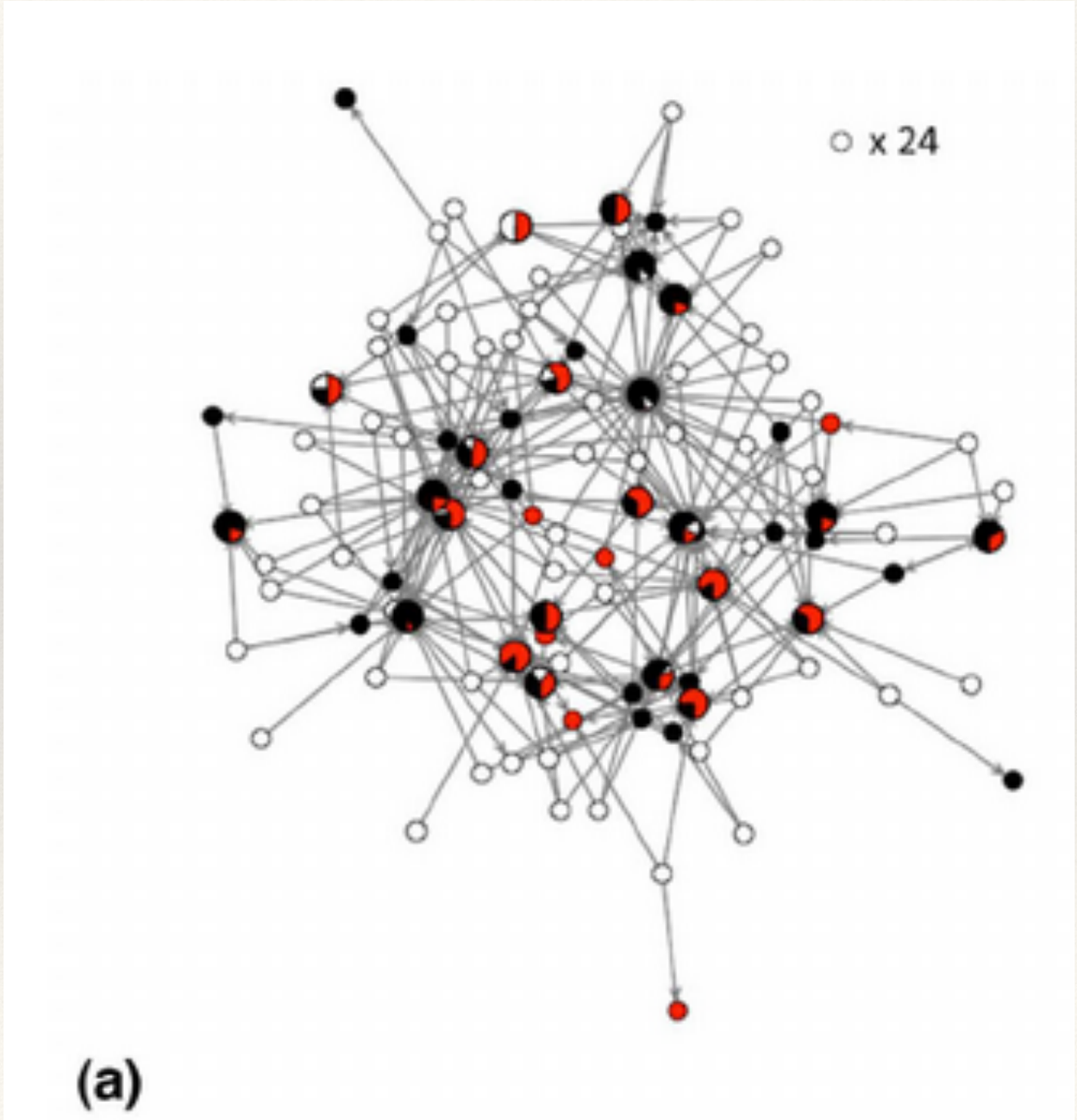
ARTICLE

CRIMINOLOGY

In the eye of the beholder: Meaning and structure of informal status in women's and men's prisons*

Derek A. Kreager[1] | Jacob T.N. Young[2] | Dana L. Haynie[3] | David R. Schaefer[4] | Martin Bouchard[5] | Kimberly M. Davidson[1]

Positive/Negative/Neutral
Power nominations



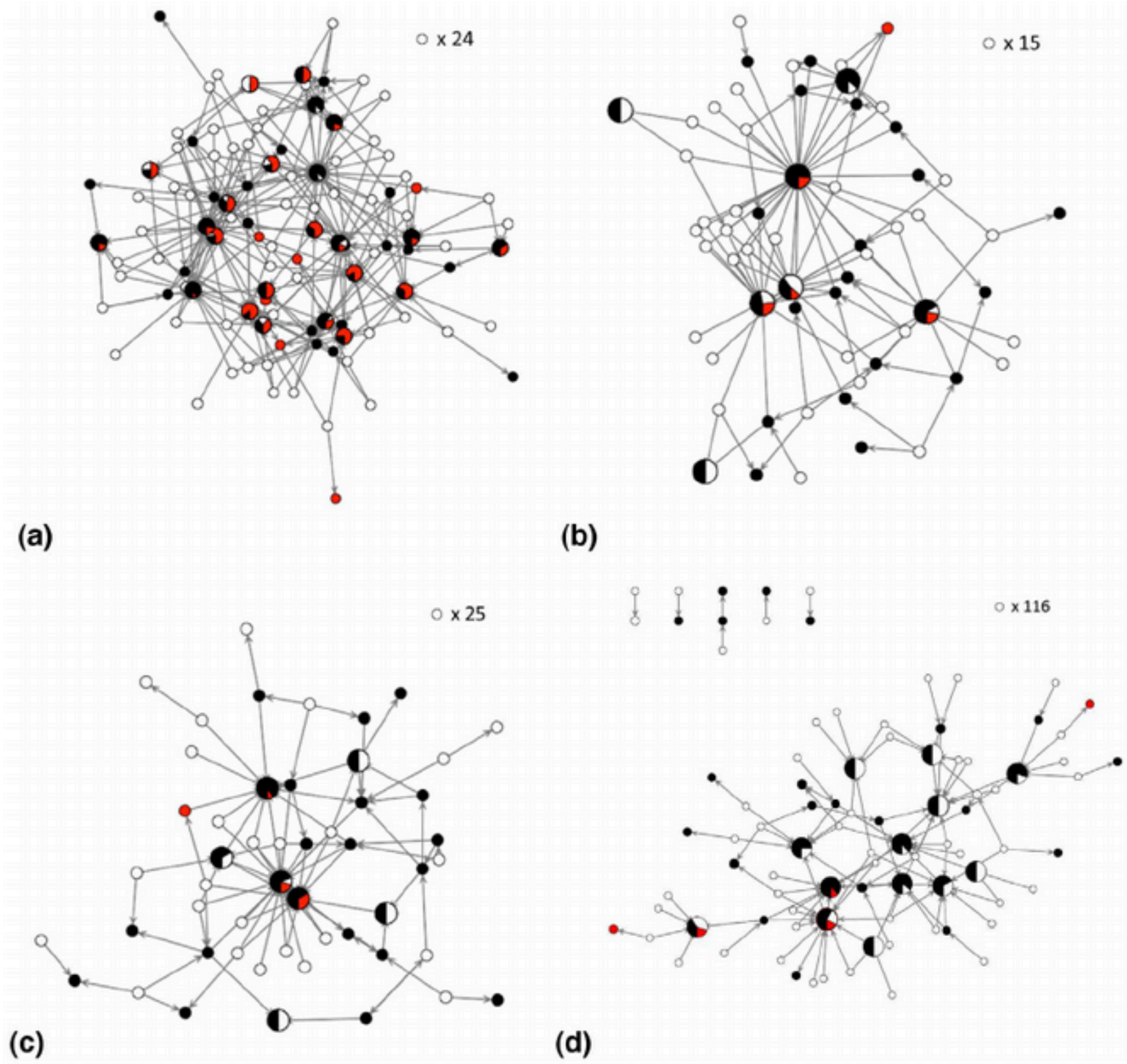
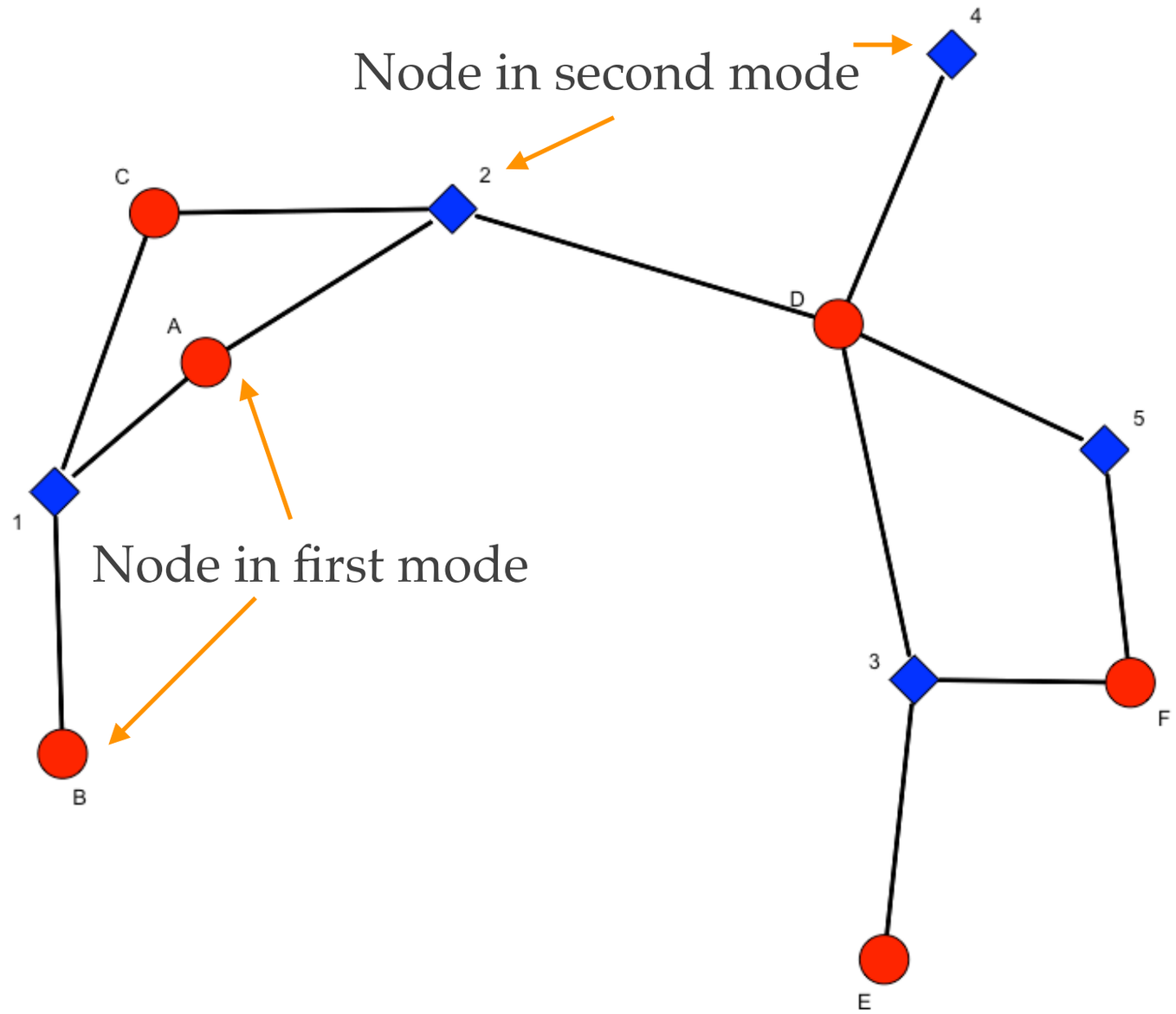


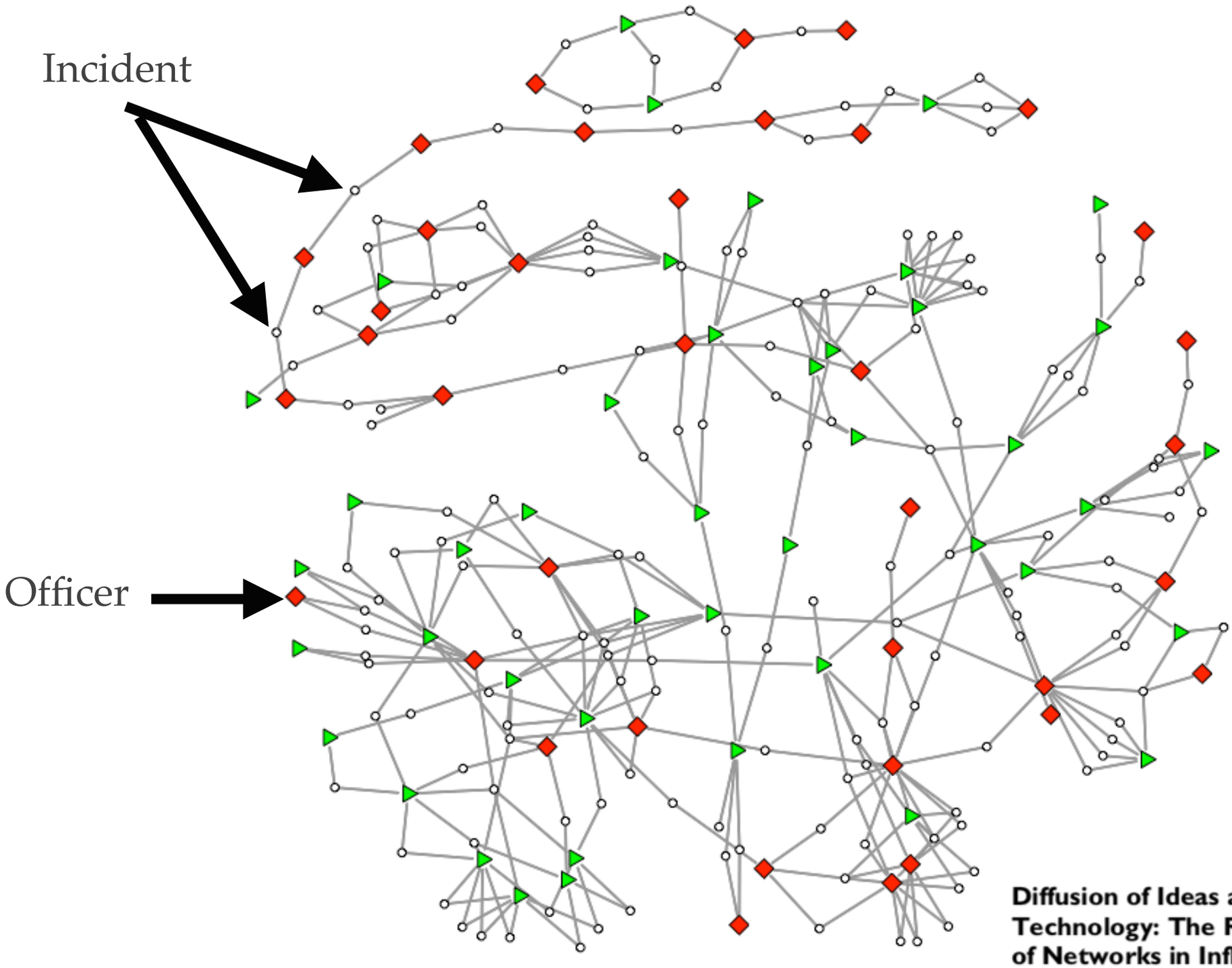
FIGURE 1 Balance of positive, neutral, and negative ties in the status networks of (a) Unit 1, (b) Unit 2, (c) Unit 3, and (d) Men's Unit [Color figure can be viewed at wileyonlinelibrary.com]
Notes: Nodes sized by indegree, isolate frequencies listed in top-right of each graph, and pie charts reflect proportion of incoming nominations that are positive [black], neutral [white], and negative [red].

Basic Data Elements

- *Networks* can differ with respect to their **nodes**:
  - One-mode/uni-partite (connections among one type of node).
  - Multi-mode/multi-partite (connections among two or more types of nodes).


Node in second mode
Node in first mode
C
2
4
A
D
5
1
3
F
B
E

Bipartite Graph of Incidents and Officers
by Treatment or Control Condition



Red/Square=Treatment Condition
Green/Triangle=Control Condition
White/Circle=Incidents

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2015, Vol. 31(3) 243–261

DOI: 10.1177/1043986214553380
ccj.sagepub.com
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Diffusion of Ideas and Technology: The Role of Networks in Influencing the Endorsement and Use of On-Officer Video Cameras

Jacob T. N. Young[1] and Justin T. Ready[1]

Am J Crim Just (2018) 43:197–221
DOI 10.1007/s12103-017-9395-5

The "Tough on Crime" Competition: a Network Approach to Understanding the Social Mechanisms Leading to Federal Crime Control Legislation in the United States from 1973–2014

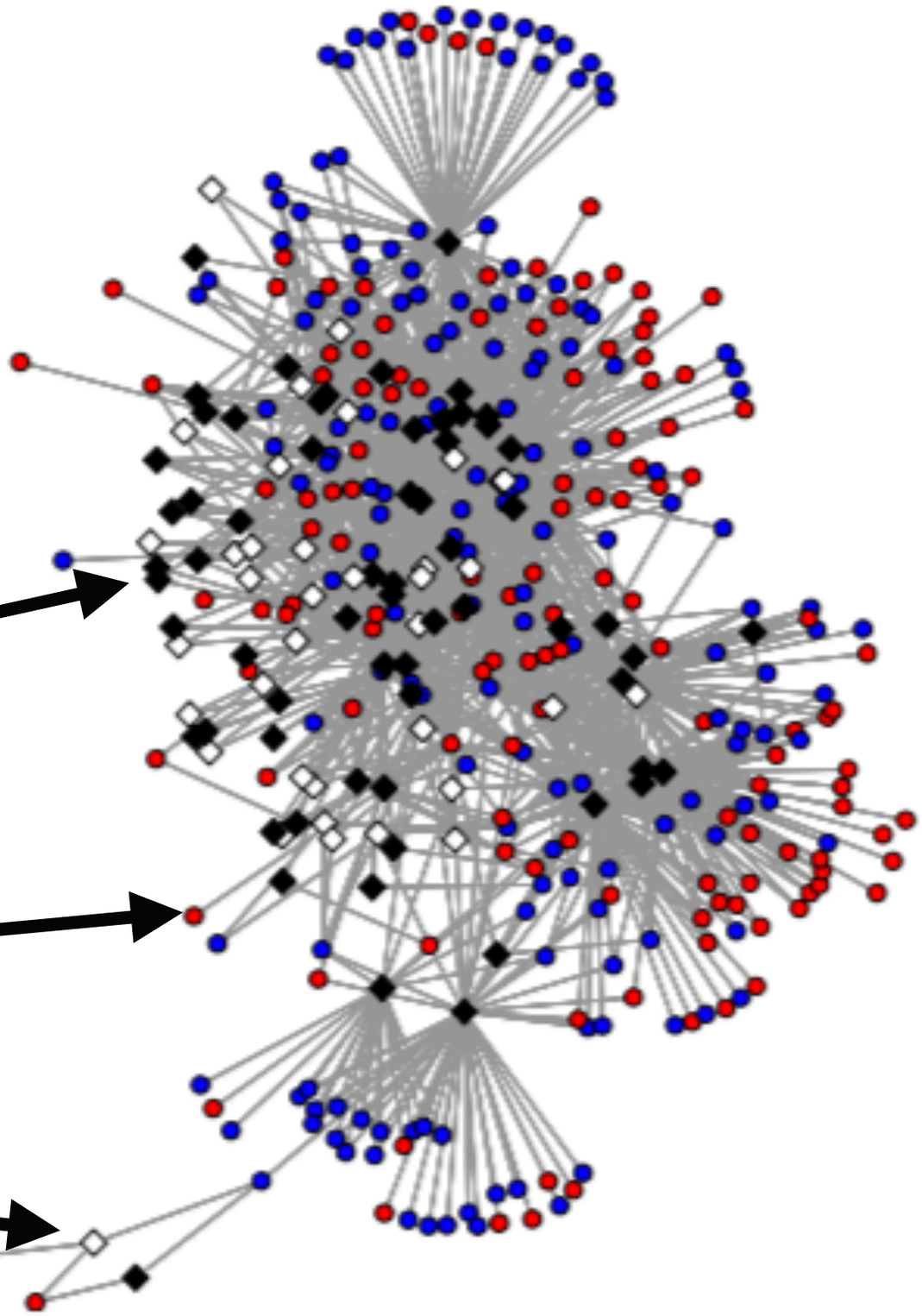
John A. Shjarback[1] · Jacob T. N. Young[2]

Crime Control Bill

Senator

Non-Crime Control Bill

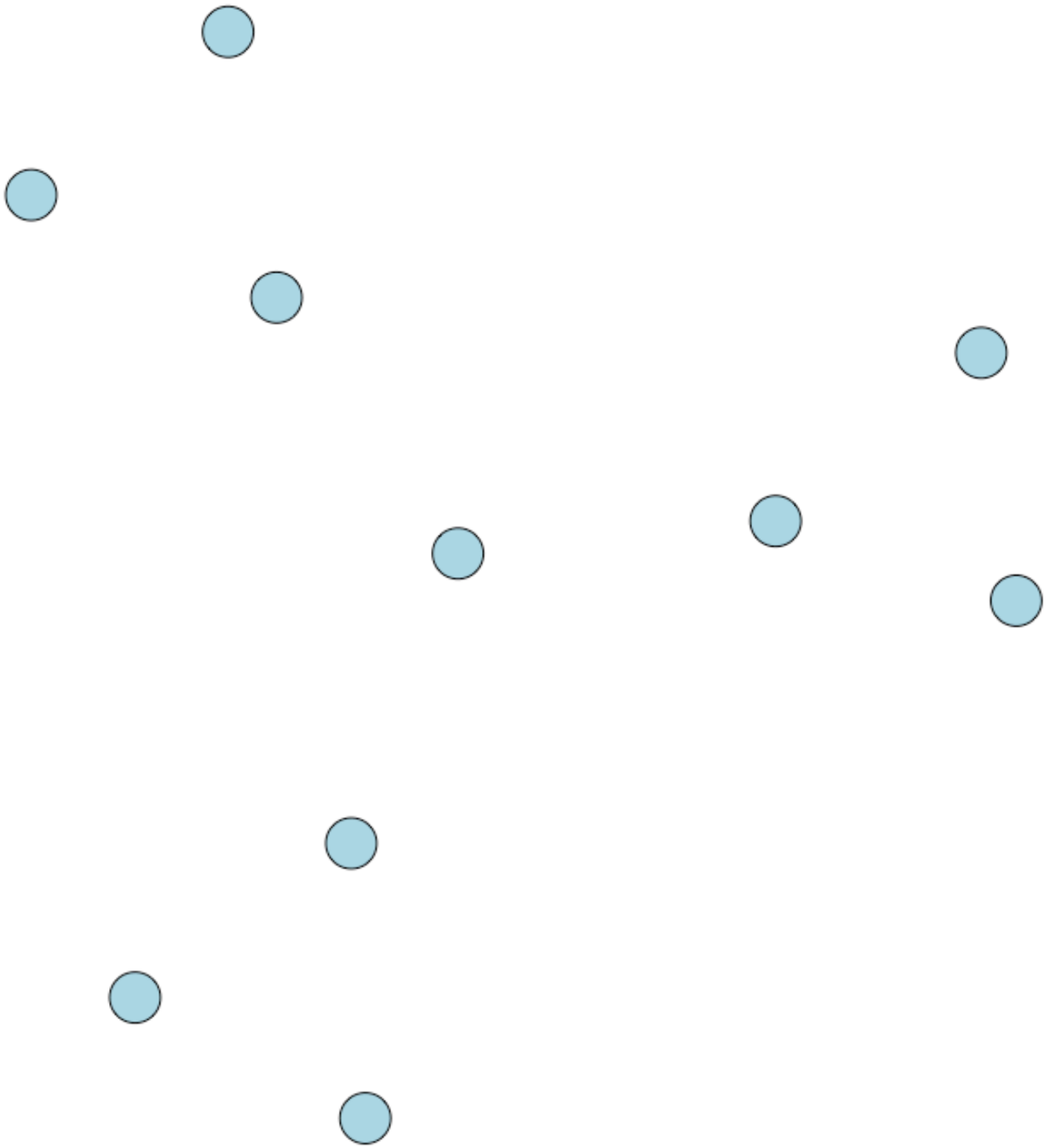
B: Plot of 291 Signers of 101 Bills in the Senate

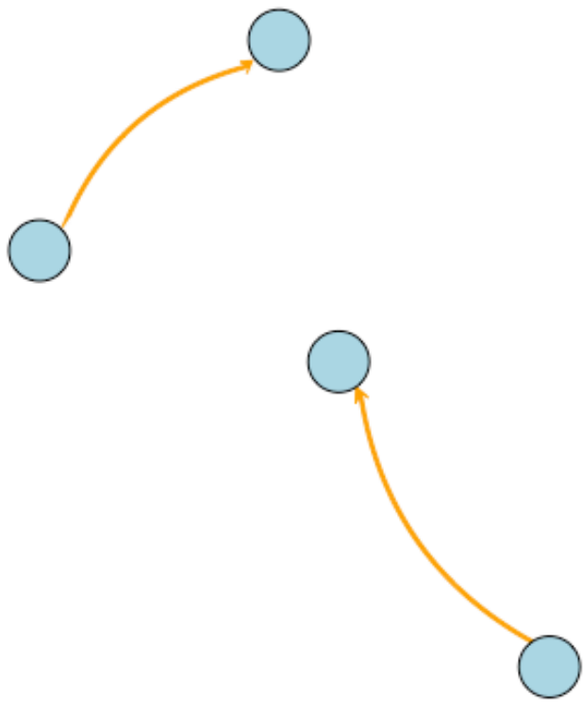


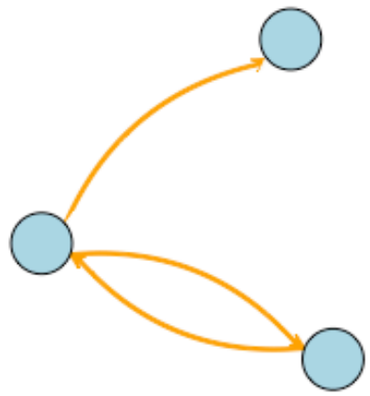
Democrats = Blue; Republicans = Red; CC Bills = Black; NCC Bills = White

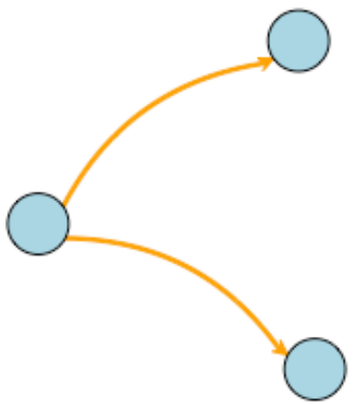
Basic Data Elements

- *Networks* can differ with respect to their **edges**:
  - Simplex (connections among nodes are of one type).
  - Multiplex (connections among nodes are of multiple types).

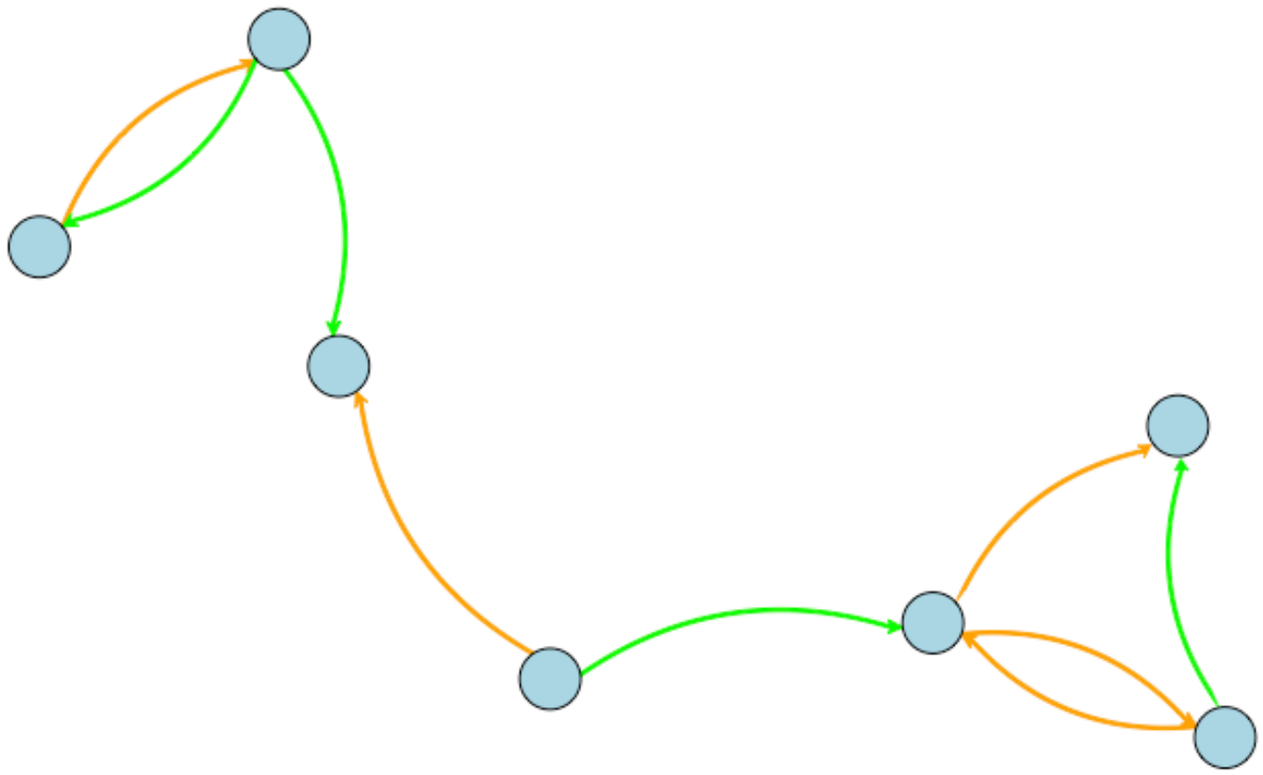


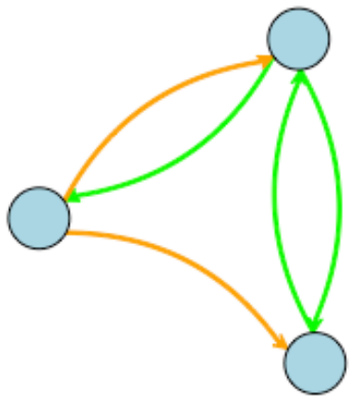






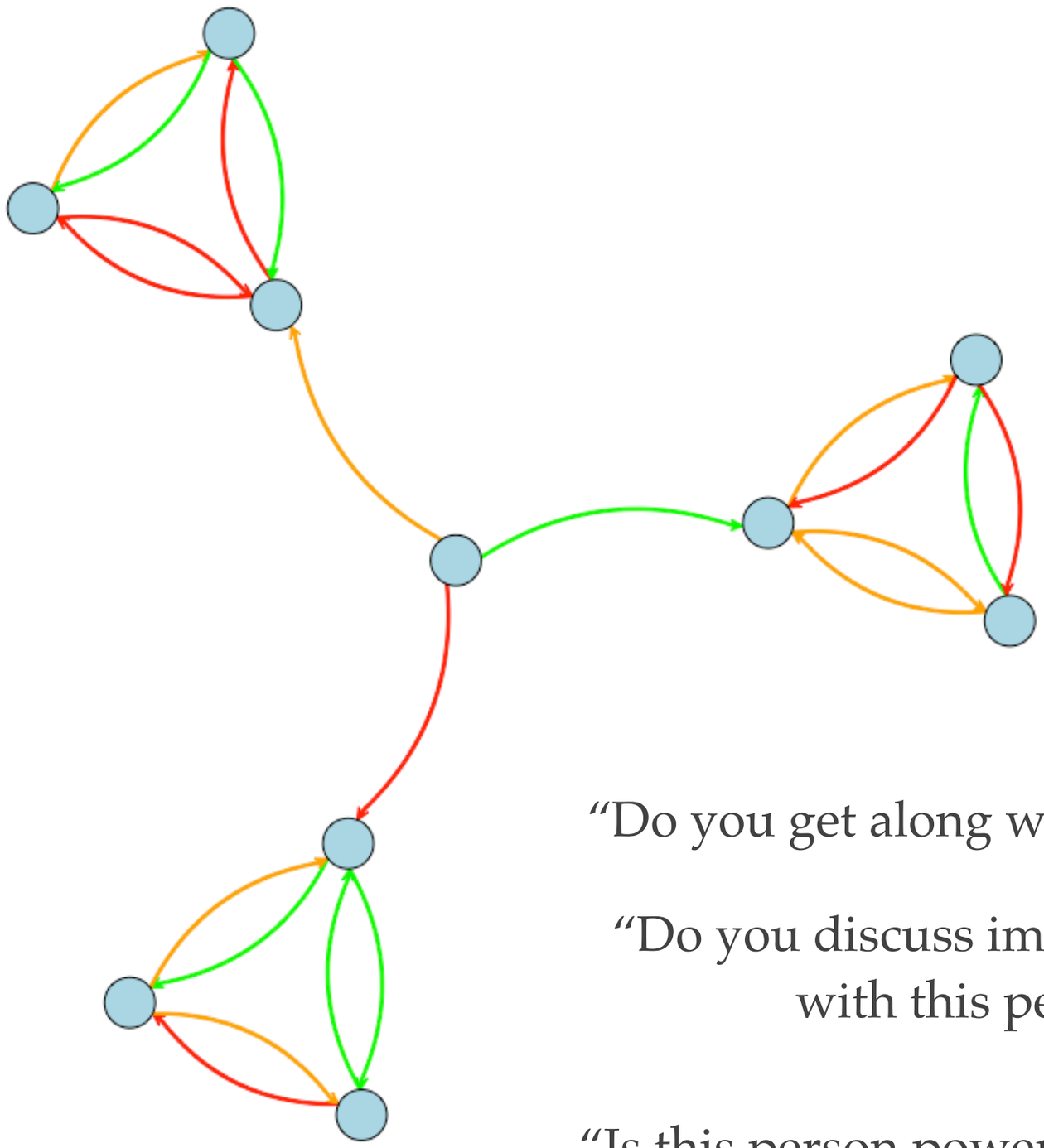
"Do you get along with this person?"





"Do you get along with this person?"

"Do you discuss important matters with this person?"



"Do you get along with this person?"

"Do you discuss important matters with this person?"

"Is this person powerful/influential?"

Questions?

Network Data Collection

How do we collect network data?

Network Data Collection

- Where do network data come from?
  - **Everywhere!**
- Types of data collection:
  - Observational (e.g. Miller project)
  - Archival (e.g. Capone project)
  - Questionnaires (e.g. Add Health, GSS)

Instruments and Design

- *Instruments* are the tools used to elicit information from respondents.
- *Design* corresponds to the protocol for determining how information should be elicited, who should be sampled, etc.
- Examples:
  - Ego-centric networks
  - Partial networks
  - Complete (global) networks

Ego-Centric Networks

- Data on a focal actor (ego) and ties to neighbors (alters) and the ties among the alters.
  - *Instrument*: name generator
    - "who are the people with whom you discuss important matters?"
    - For each person named, "which of these individuals discuss important matters"?
    - Why?-costs, generalizability, interest in local structure.

Partial Network

- Ego networks, plus some amount of tracing to reach contacts of contacts.
  - *Instrument*: tracing mechanism
    - Using tickets to trace across a network
    - Why?-difficult to reach population, hard to specify sampling frame.
      - **Does this instrument seem familiar?**

Complete (Global) Network

- Data on all actors within a particular (defined) boundary, sampling frame is known.
  - *Instruments*:
  - roster
    - "For each of the following persons, please indicate whom you trust?"
  - Free response
    - "Who are the people in this school that you trust?"

Things to consider…

- Domain:
  - "What type of network is this?"
- Sample:
  - "What is the population of interest and how was it sampled?"
- Temporality:
  - "Are the data cross-sectional or longitudinal?"
  - "Is it a panel or continuous measurement?"
- Tie Meaning:
  - "Are ties discrete events or enduring states?"
- Instrument:
  - "How was the information collected?"

Things to keep in mind…

- Butts (2009: 24)
  - Representational formalism:
    - "Researchers begin with a finite set of identifiable entities…"
  - "This representational framework is quite restrictive. To represent a system in this way, we must be able to reduce it to a well-defined set of discrete components whose interactions are strictly dyadic in nature…; although such a framework may seem so restrictive as to useless, its typical purpose is to serve as an approximation…"

More things to keep in mind…

- *What is the level of analysis?*
  - Dyad Level
    - "are individuals whose offices are close to each other more likely to be friends?"
  - Node Level
    - "are more popular youth more likely to engage in unprotected sex?"
  - Network Level
    - "do viruses spread faster in particular network structures?"

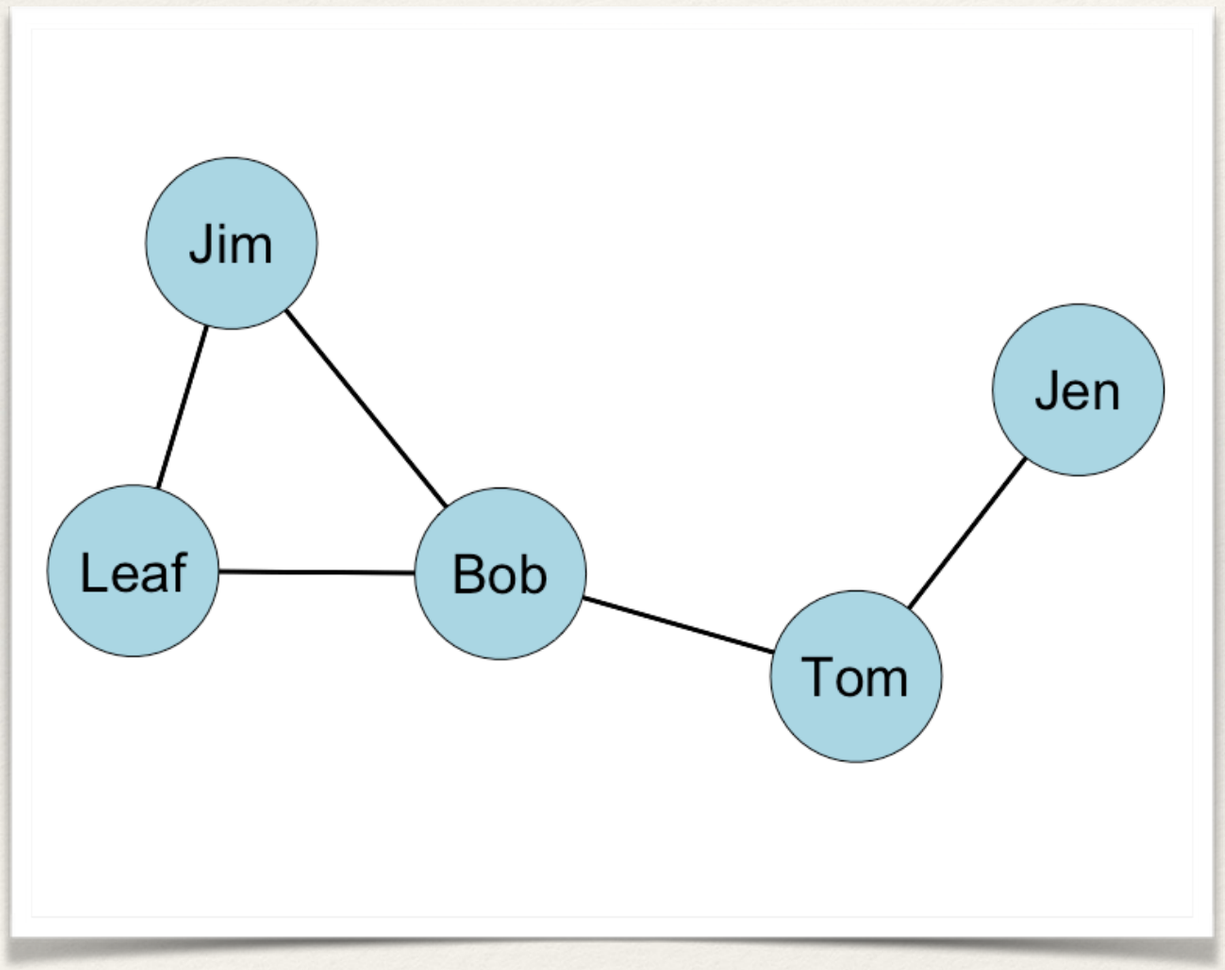
Representing Networks with Graphs and Matrices

*What do network **data** "look like"?*

Sociometric Notation

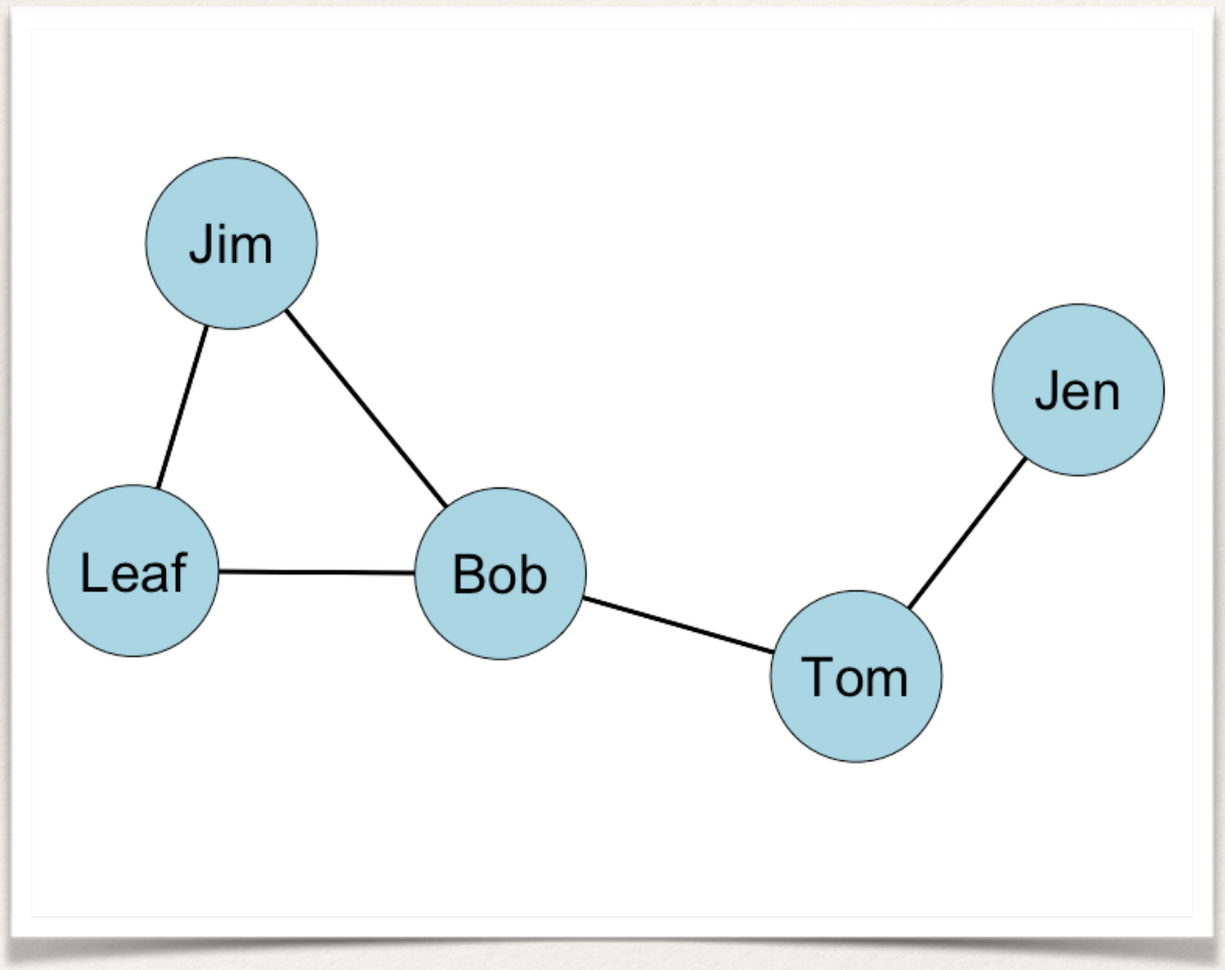
- For a set of relations, ***X***, we can define a matrix which represents these relations.
- We commonly use an *adjacency matrix*, where each node/vertex is listed on the row and the column.
- The i_{th} row and the j_{th} column X_{ij} records the value of a tie from i to j.
- In this approach, ***X***, can be thought of as a variable.
  - The presence or absence of values in the cells represent variation.

Example: Undirected, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen					
Tom					
Bob					
Leaf					
Jim					

Example: Undirected, Binary Network

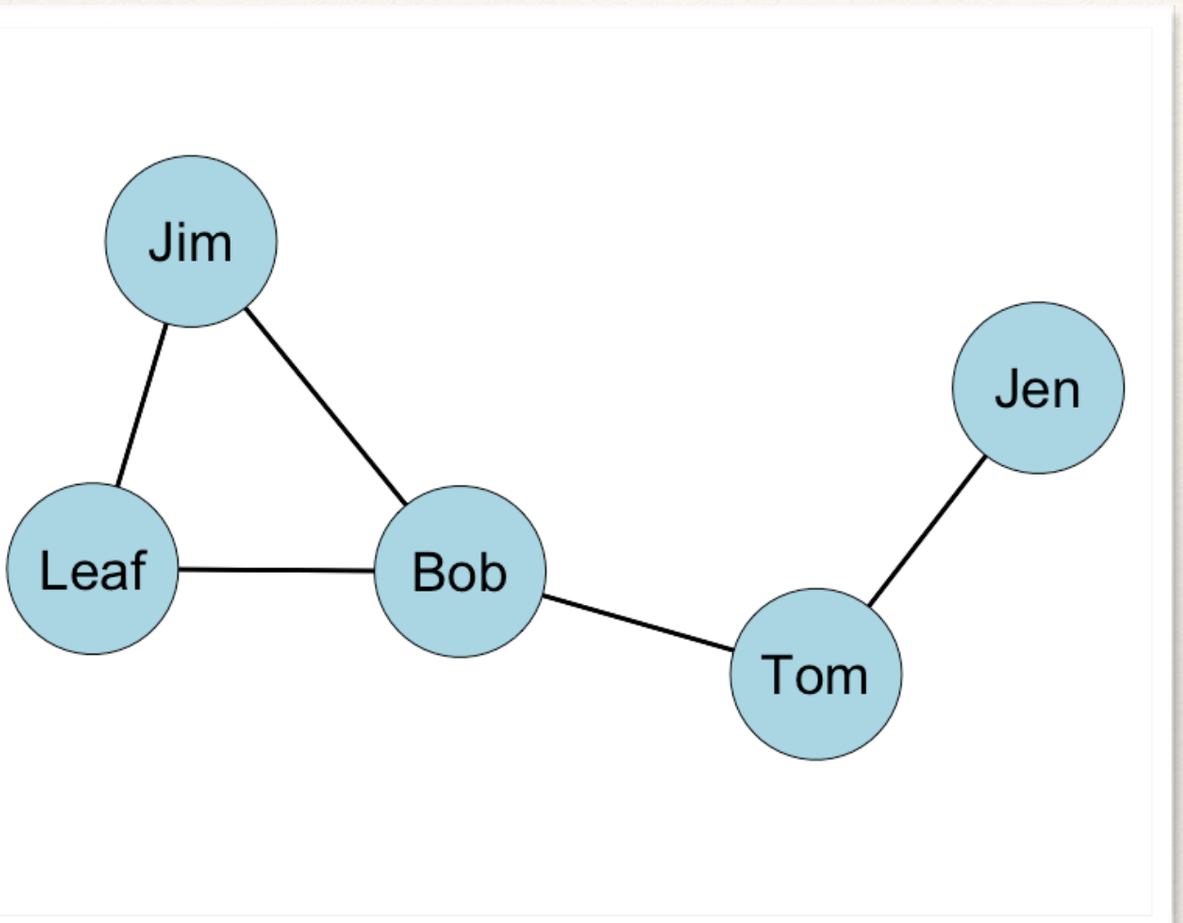


Graph or Sociogram

	Jen	Tom	Bob	Leaf	Jim
Jen					
Tom					
Bob					
Leaf					
Jim					

Adjacency Matrix or Sociomatrix

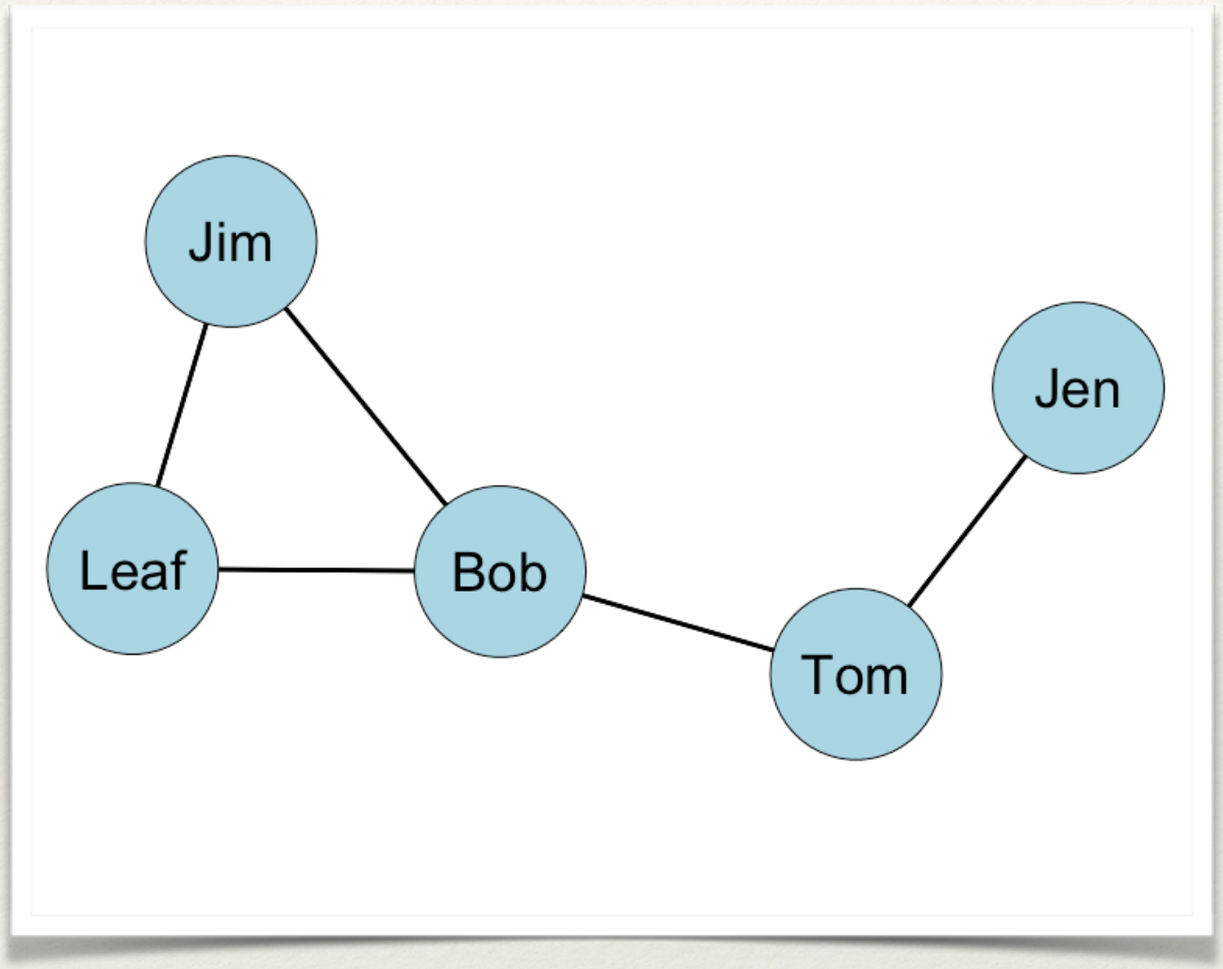
Example: Undirected, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen					
Tom					
Bob					
Leaf					
Jim					

We don't allow (in the simple case) self-nominations, so the diagonal is undefined.

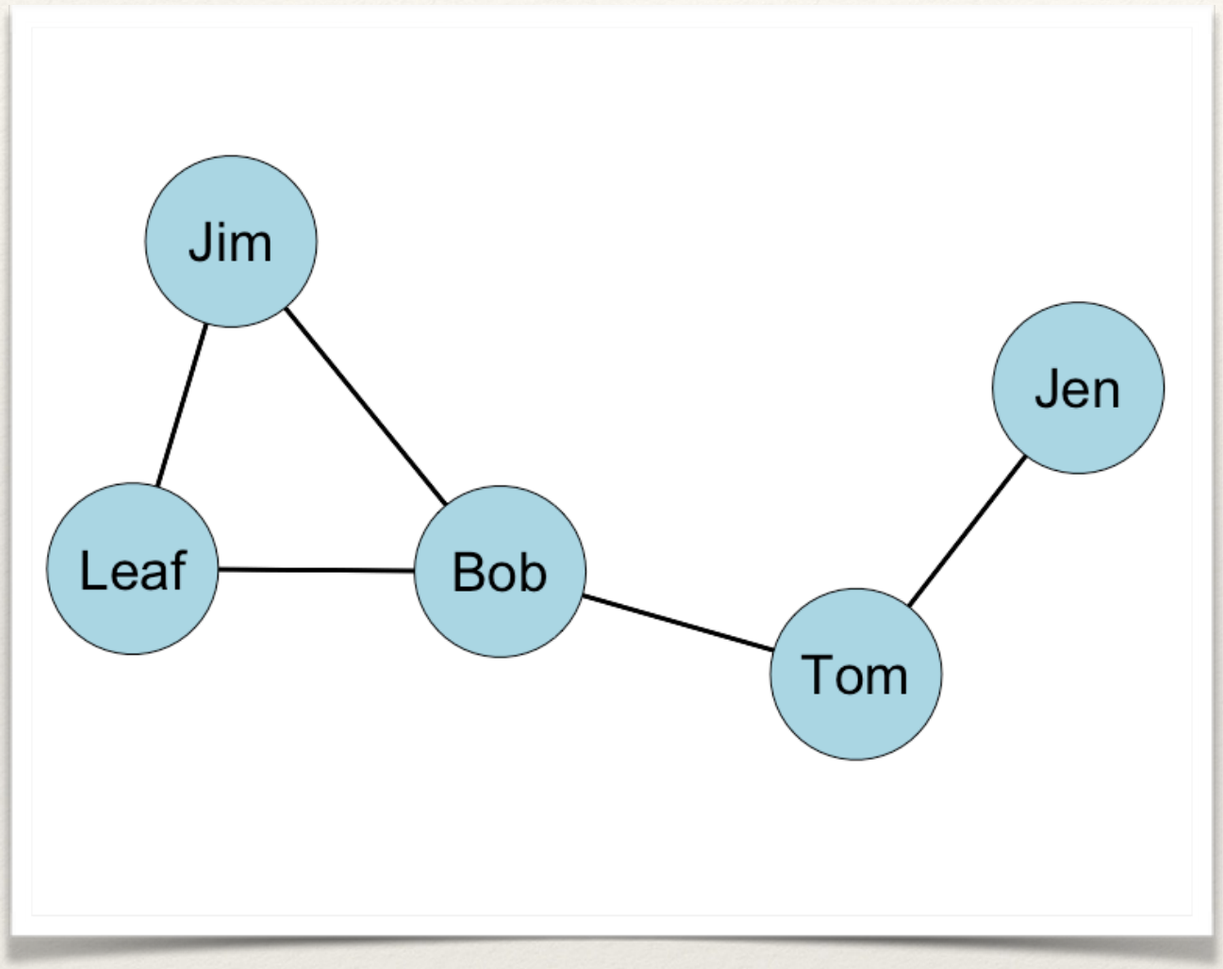
Example: Undirected, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen		1	0	0	0
Tom					
Bob					
Leaf					
Jim					

In the first row, i sends to the second row only: $X_{12} = 1; X_{15} = 0$

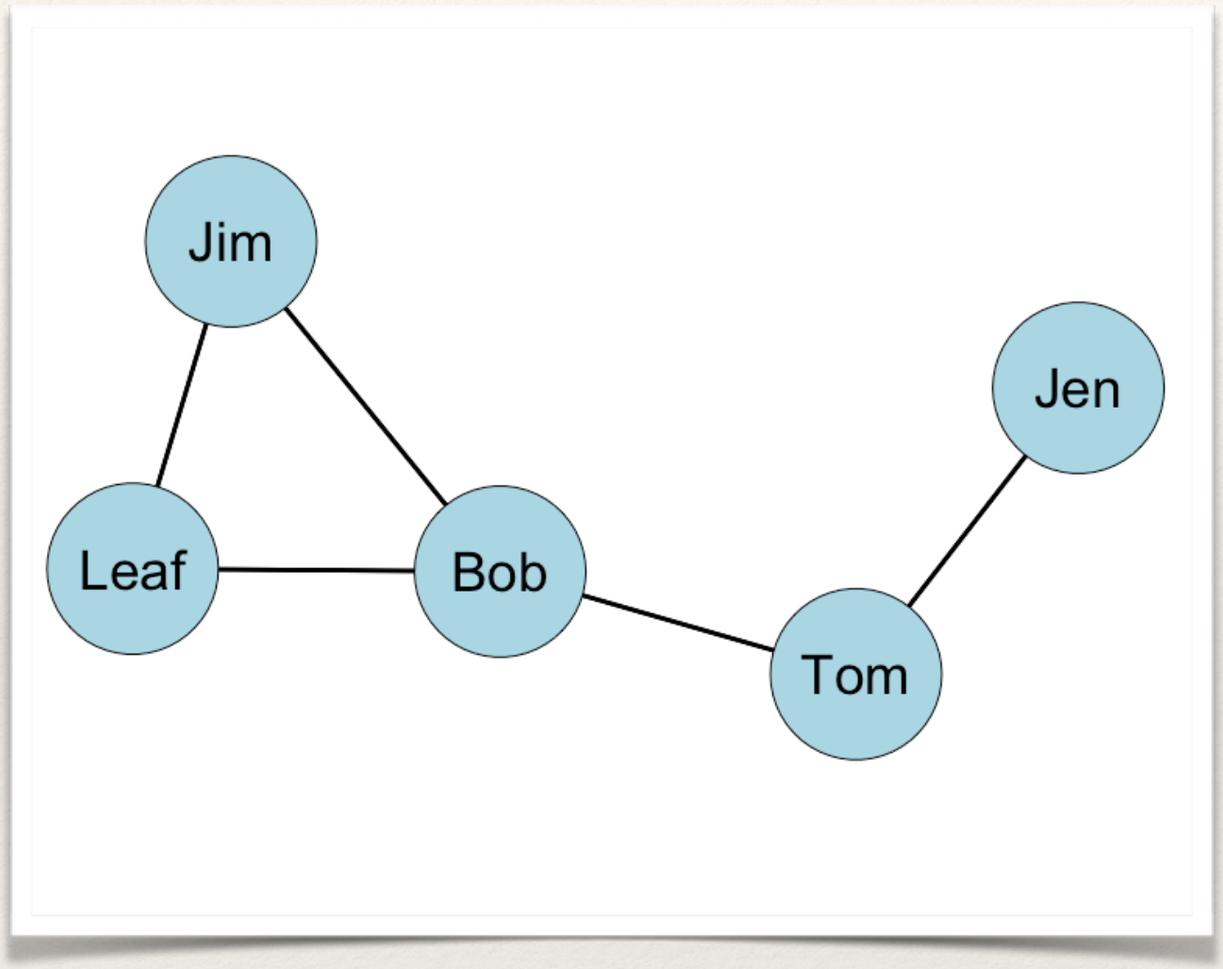
Example: Undirected, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen		1	0	0	0
Tom	1				
Bob	0				
Leaf	0				
Jim	0				

Since this is *undirected*, it is **symmetric** about the diagonal.
This means that the *ith* column is the transposition of the *ith* row.

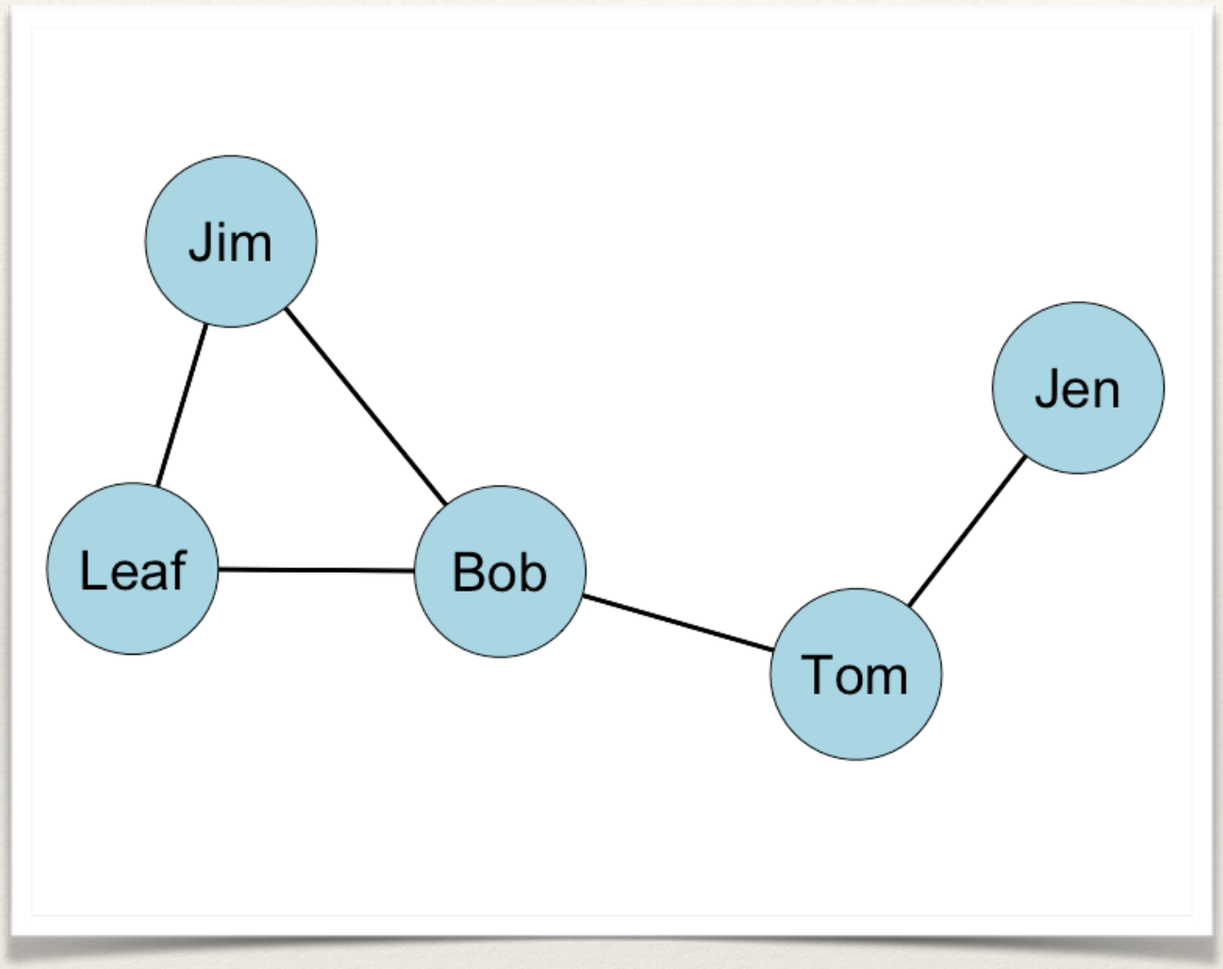
Example: Undirected, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen		1	0	0	0
Tom	1				
Bob	0				
Leaf	0				
Jim	0				

What does the rest of the matrix look like?

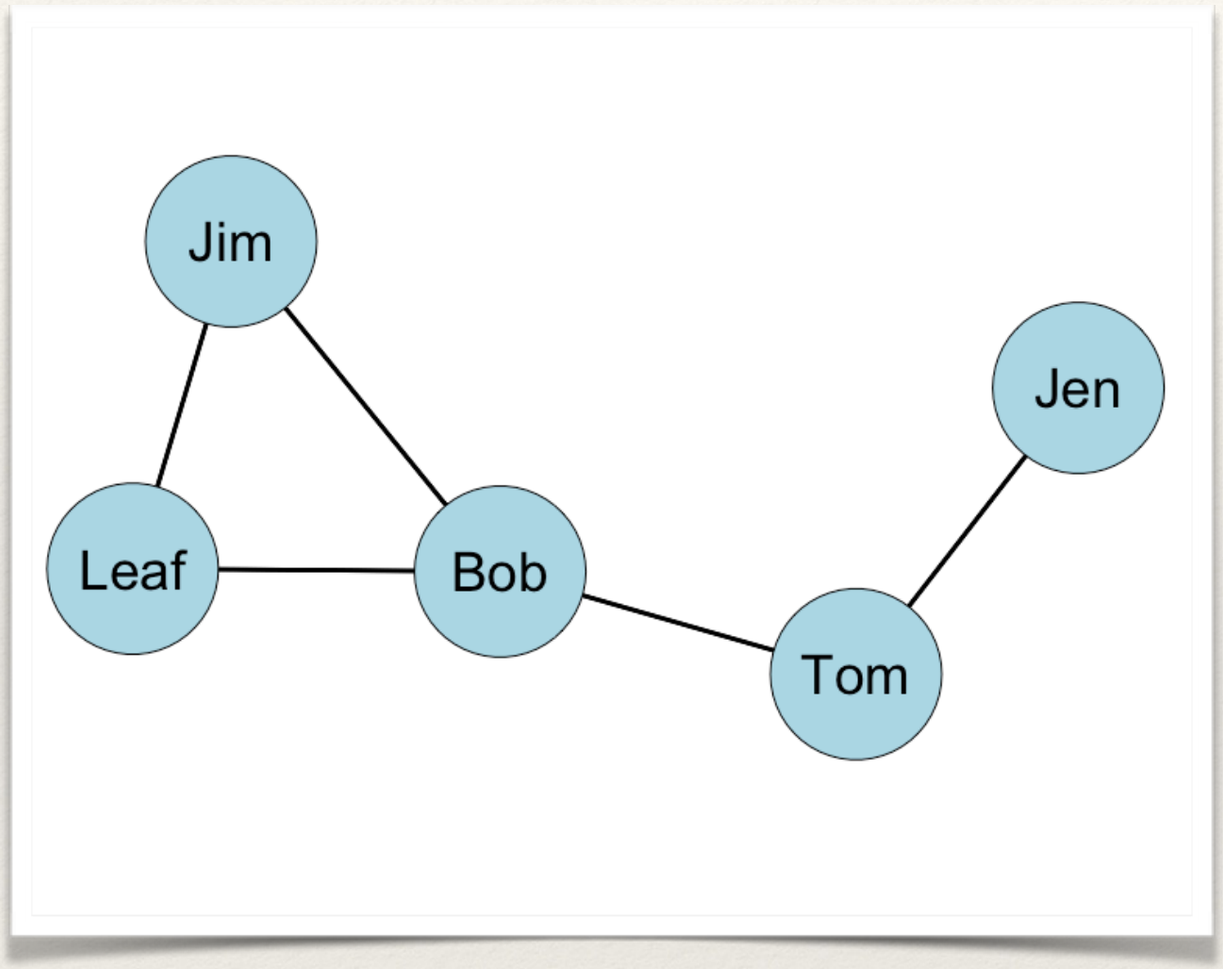
Example: Undirected, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen		1	0	0	0
Tom	1		1	0	0
Bob	0	1		1	1
Leaf	0	0	1		1
Jim	0	0	1	1	

It looks like this.

Example: Undirected, Binary Network

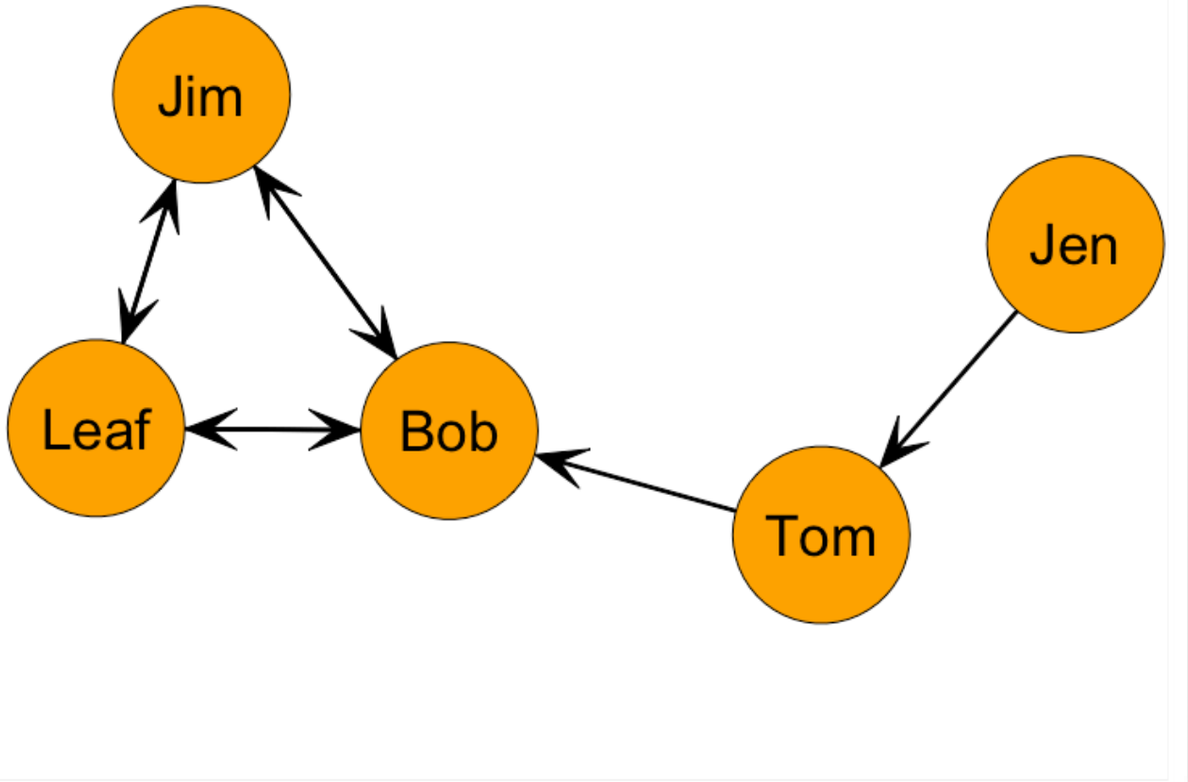


It looks like this.

Let's add zeros to the diagonals. (will explain this later…)

	Jen	Tom	Bob	Leaf	Jim
Jen	0	1	0	0	0
Tom	1	0	1	0	0
Bob	0	1	0	1	1
Leaf	0	0	1	0	1
Jim	0	0	1	1	0

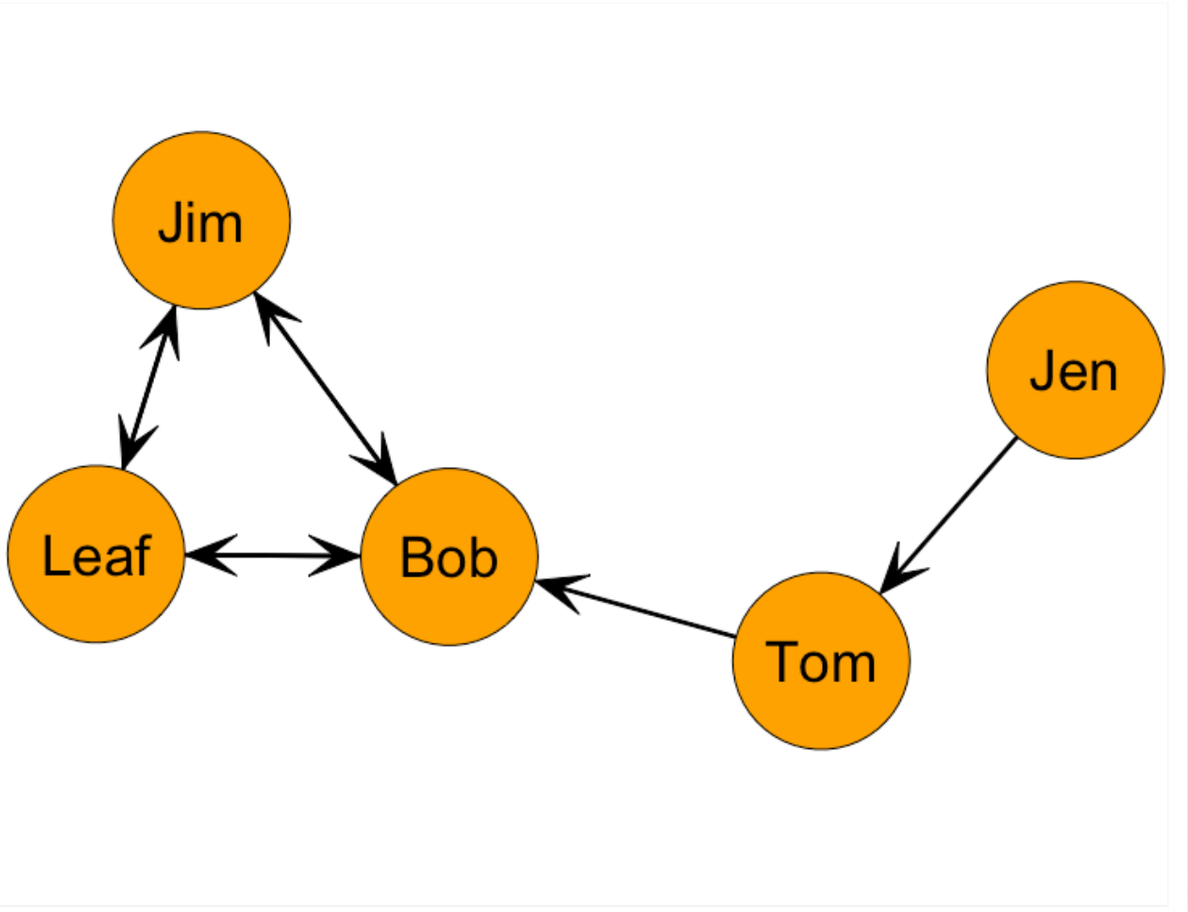
Example: Directed, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen					
Tom					
Bob					
Leaf					
Jim					

What's different about a directed network?

Example: Directed, Binary Network

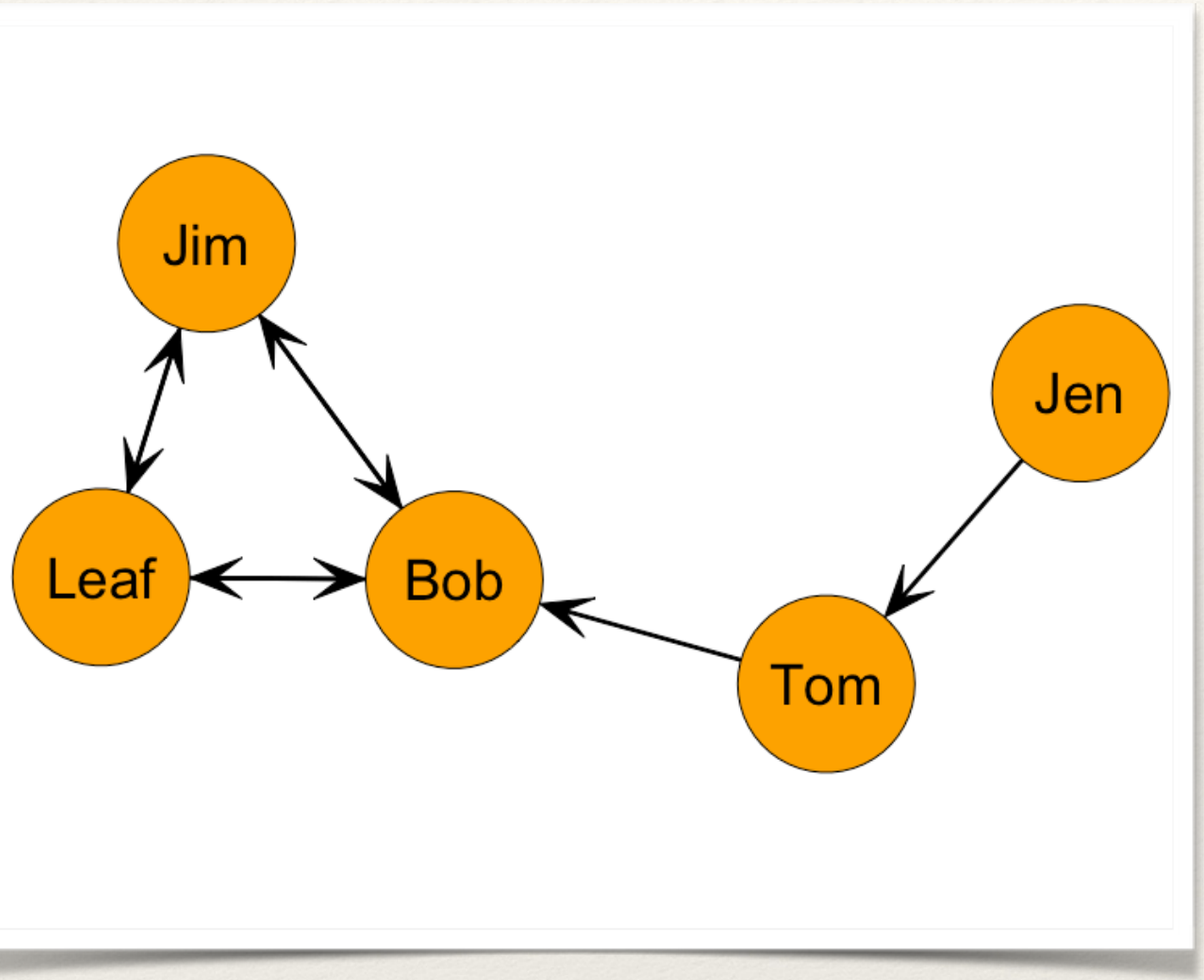


	Jen	Tom	Bob	Leaf	Jim
Jen		1			
Tom					
Bob					
Leaf					
Jim					

In the first row, i sends to the second row:

$$X_{12} = 1$$

Example: Directed, Binary Network

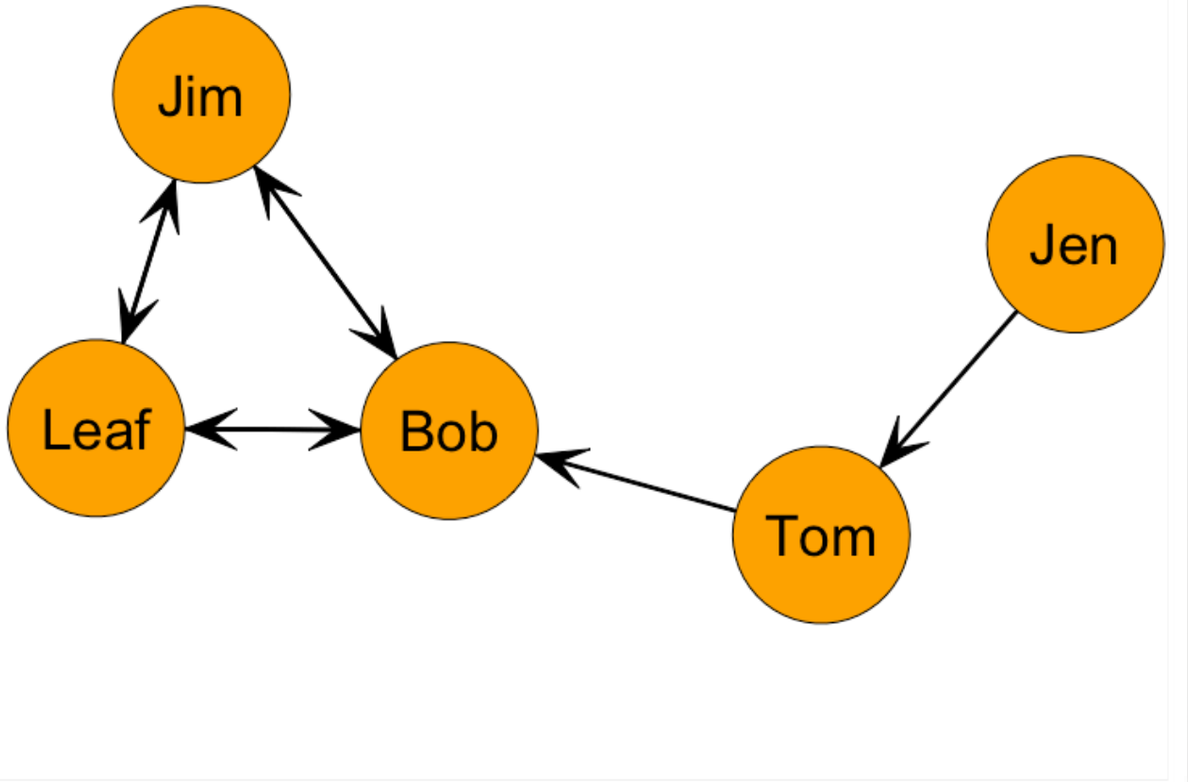


	Jen	Tom	Bob	Leaf	Jim
Jen		1			
Tom	0				
Bob					
Leaf					
Jim					

But in the second row, j does not send:

$X_{21} = 0$

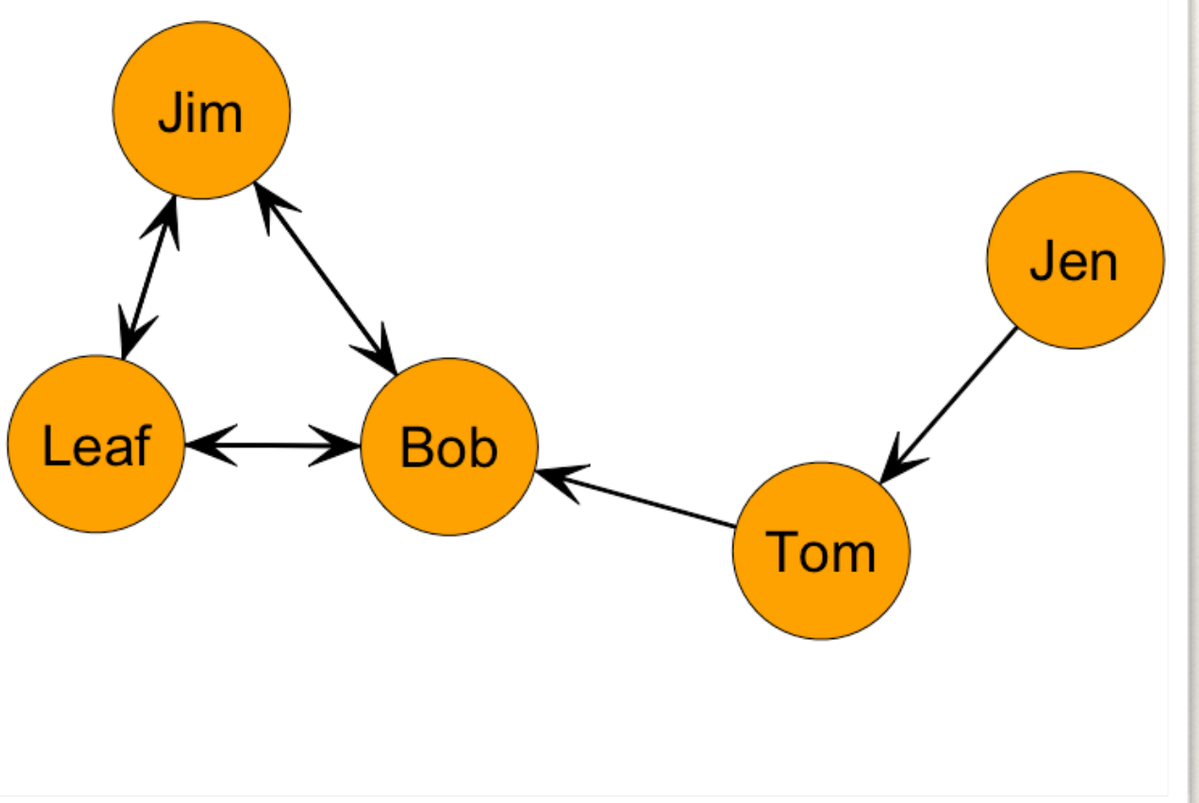
Example: Directed, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen		1			
Tom	0				
Bob					
Leaf					
Jim					

The Jen/Tom dyad is **asymmetric**. So, directed graphs permit asymmetry.

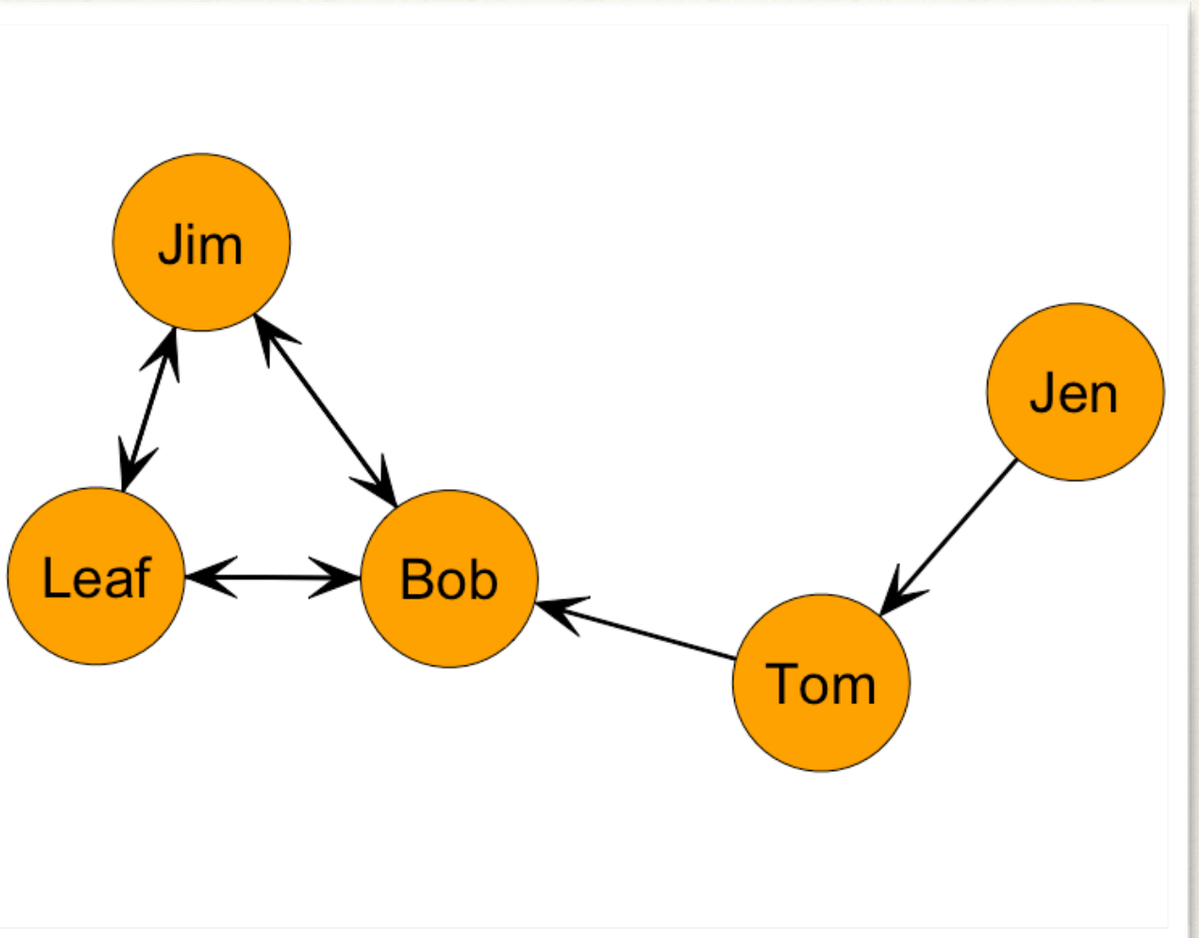
Example: Directed, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen		1			
Tom	0				
Bob				1	
Leaf			1		
Jim					

What about the Leaf/Bob dyad? Is it **asymmetric** or is it **symmetric**?

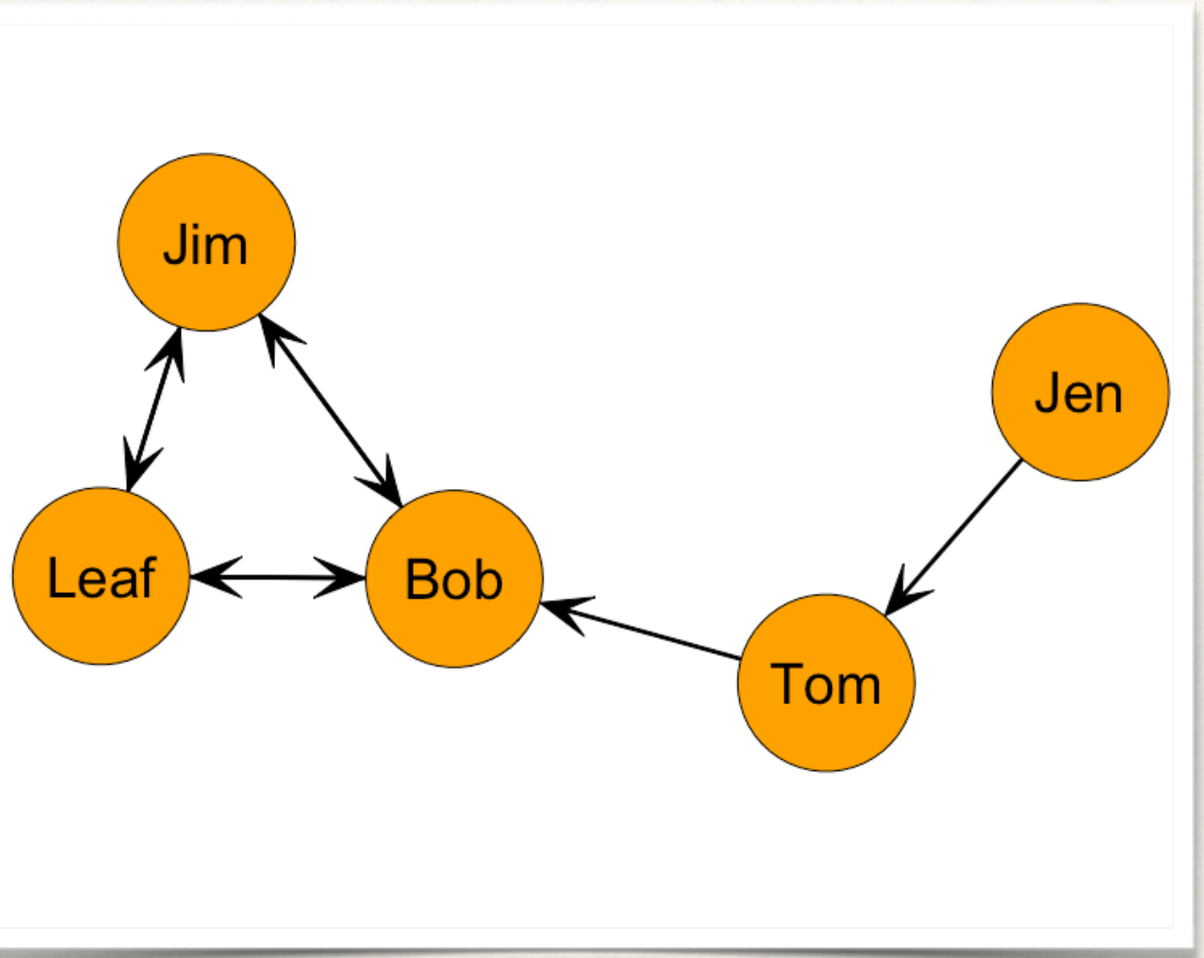
Example: Directed, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen		1			
Tom	0				
Bob				1	
Leaf			1		
Jim					

What does the rest of the matrix look like?

Example: Directed, Binary Network



It looks like this.

Let's add zeros to the diagonals. (will explain this later…)

	Jen	Tom	Bob	Leaf	Jim
Jen	0	1	0	0	0
Tom	0	0	1	0	0
Bob	0	0	0	1	1
Leaf	0	0	1	0	1
Jim	0	0	1	1	0

Extensions

- We can use matrices to represent other types of network data.
- Valued, Weighted, Signed, etc.
- Multiple modes

Questions?

Basic Network Analysis

Description vs. Inference

- Description
  - What proportion of possible ties are observed? (density)
  - Who has the most ties? (degree centrality)
  - Are there clusters in the network? (graph modularity/subgroup analysis)

- Inference
  - How did this graph form? (Exponential random graph models)
  - Why do nodes change their edges? (Stochastic actor based models)
  - Do edges/nodes influence nodes/edges? (Co-evolution models)

Network Science

- <u>REMEMBER YOUR RESEARCH METHODS:</u>
  Conceptualization and Operationalization

- Network science **conceptualizes** theoretical concepts that are inherently relational (we will talk about this more next lecture).

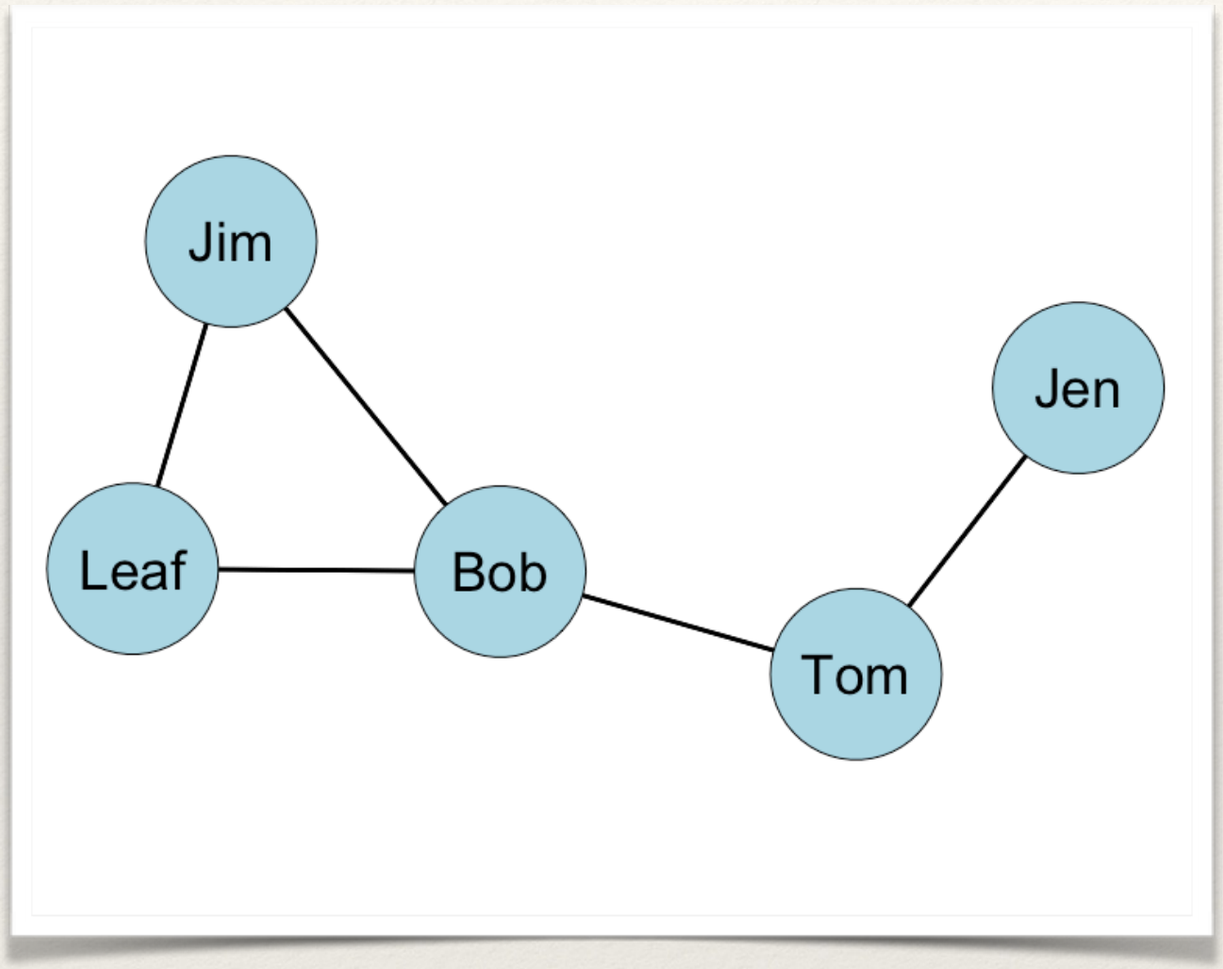
- Network research **operationalizes** theoretical constructs by drawing on the formal properties of graphs.

When we say a *node* is "central"
what do we mean conceptually?

Degree Centrality: Undirected Binary Graphs

- In an undirected binary graph, *actor degree centrality* measures the extent to which a node connects to all other nodes in a social network.
  - In other words, the number of edges incident with a node.
    - This is symbolized as: $d(n_i)$
      - For an undirected binary graph, the degree $d(n_i)$ is the row or column sum.

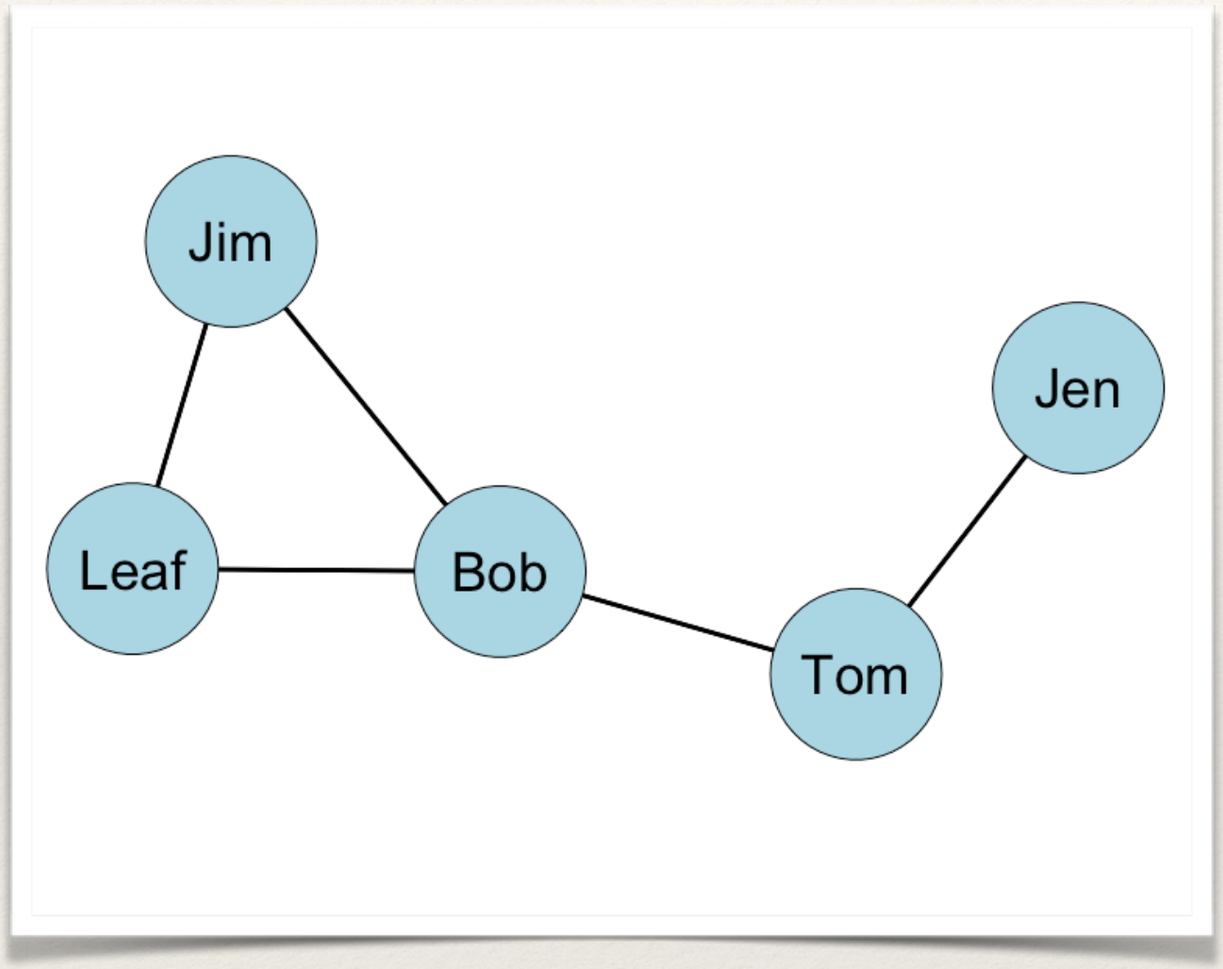
Example: Undirected, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen	0	1	0	0	0
Tom	1	0	1	0	0
Bob	0	1	0	1	1
Leaf	0	0	1	0	1
Jim	0	0	1	1	0

What is the degree for each node in this graph?

Example: Undirected, Binary Network



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Note that the column sum and row sum are the same.

Summarizing Degree Centrality

- We can examine the summary statistics for degree centrality by inspecting the **mean**.
- The average degree is an important property of a network.
  - *Why? What does a network with a high average degree look like? A low average degree?*

Questions?