Social Networks "Crash Course"

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Goal: Answer some questions

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

Schedule

- 9:00-9:30 Introductions and Overview
- 9:30-10:15 Basics of Network Science
- 10:15-10:30 Break
- 10:30-11:30 Network Data Structures and Analysis
- 11:30-12:00 Wrap-Up and Questions

Introductions

Who are you and why are you here?

Motivating Question

What determines whether a police officer activates their body-camera during an incident?

Empirical Example

Journal of Contemporary Criminal Justice
2015, Vol. 31(3) 243–261

DOI: 10.1177/1043986214553380
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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]

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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]

- Questions:
  - How do police officers "frame" body-worn cameras?
  - Is the meaning officers attribute to cameras created and transmitted in groups?

Empirical Example

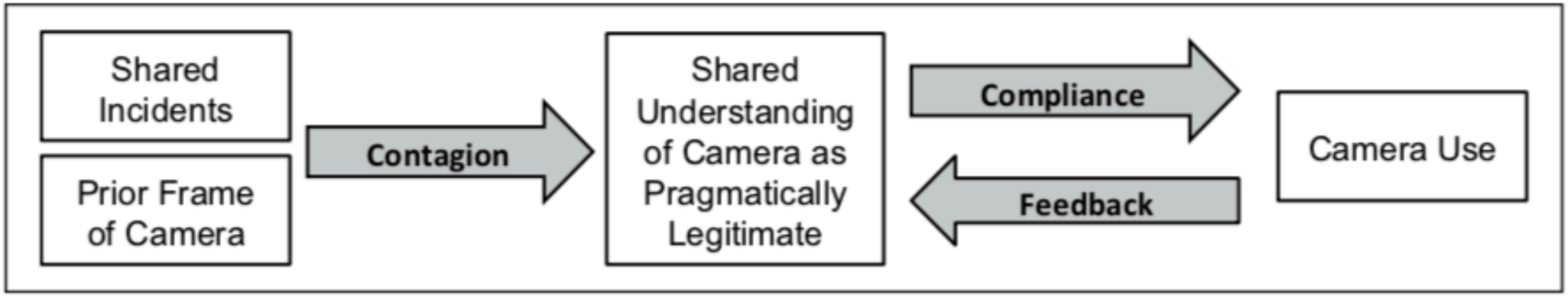

Figure 1. Diffusion of pragmatic legitimacy frame and compliance.

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**).

    - *What are some ways people can be connected?*

Network Science

- Network science takes these *relational structures* as the primary domain of interest:
  - How does the network matter? (explanan/IV)
  - What effects (affects?) the network? (explanandum/DV)

Network Analysis

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

Example

- Consider three different questions:
  - Are kids who are risk-seeking more likely to drink alcohol?
  - Are kids who have friends that drink alcohol more likely to drink alcohol?
  - Are kids who drink alcohol more likely to be popular?

Example

- <u>Consider three different questions</u>:
  - Are kids who are risk-seeking more likely to drink alcohol?
  - Are kids who have friends that drink alcohol more likely to drink alcohol?
  - Are kids who drink alcohol more likely to be popular?

- *How are these questions different? Is the causal logic the same? Are the policy implications the same? What are the variables?*

NEWS IN BRIEF

Sudden Death Of Aunt Creates Rupture In Family Gossip Pipeline

11/23/15 8:45am • SEE MORE: LOCAL

https://local.theonion.com/sudden-death-of-aunt-creates-rupture-in-family-gossip-p-1819578447

Sudden Death Of Aunt Creates Rupture In Family Gossip Pipeline

VIRGINIA BEACH, VA—Grieving family members of local aunt Laurie Shelton confirmed Monday that the 48-year-old woman's unexpected death had caused a major breach in their gossip pipeline, suddenly disrupting access to the latest dirt on all their relatives. "Since Aunt Laurie passed, news about how Stephanie's new boyfriend can't hold down a job and updates on Uncle Jeff's gambling habit have slowed to a trickle," said Shelton's niece Arielle, mourning the loss of a woman who for years had reportedly ensured a steady stream of the juiciest tidbits about relatives' layoffs, unplanned pregnancies, personal bankruptcies, and misdemeanor shoplifting charges. "All the best gossip flowed through her, and now she's gone. For all I know, the twins in North Carolina could have been caught smoking pot, Grandma could be back together with Leon, and Uncle Mike could be considering a vasectomy. It's a devastating loss for the whole family." Several in the family expressed hope that, for the time being, a sufficient supply of idle chatter could be rerouted through Cousin Staci to meet their immediate needs.

Conceptually, what does this story tell us about the **relational structure** of information transmission in the Shelton family?

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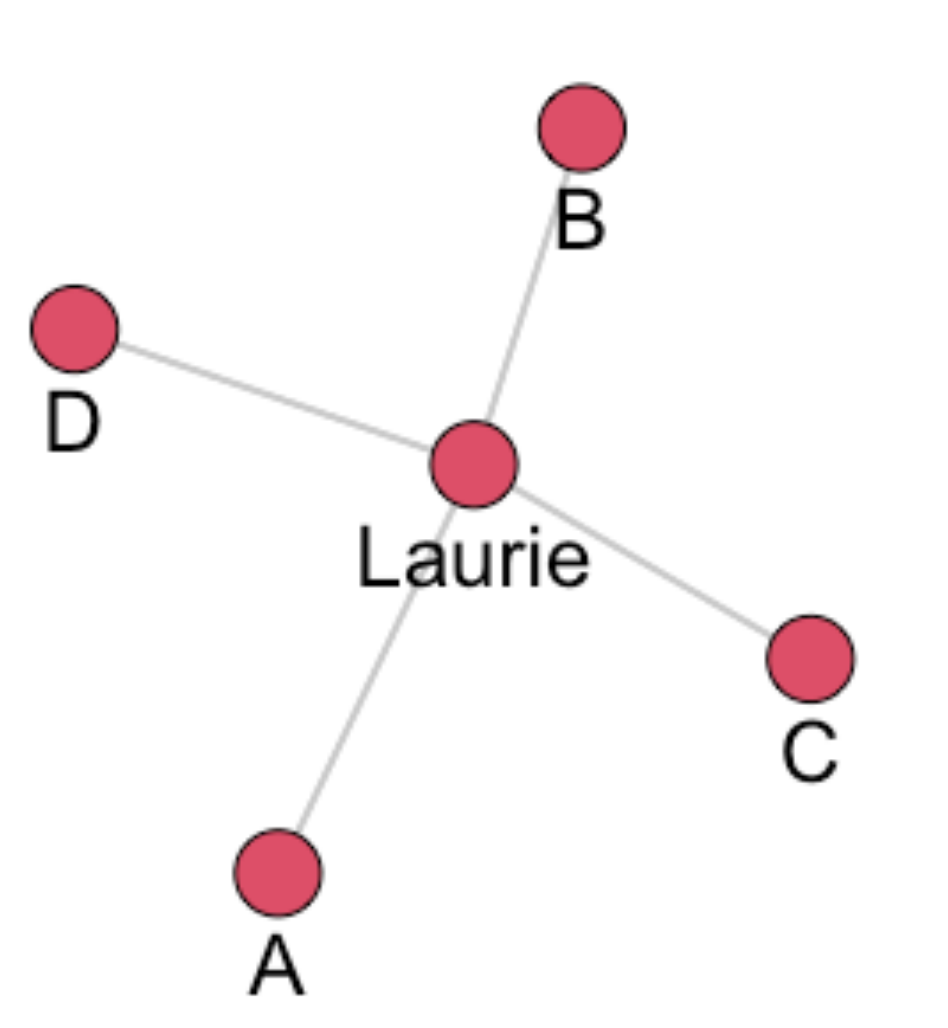
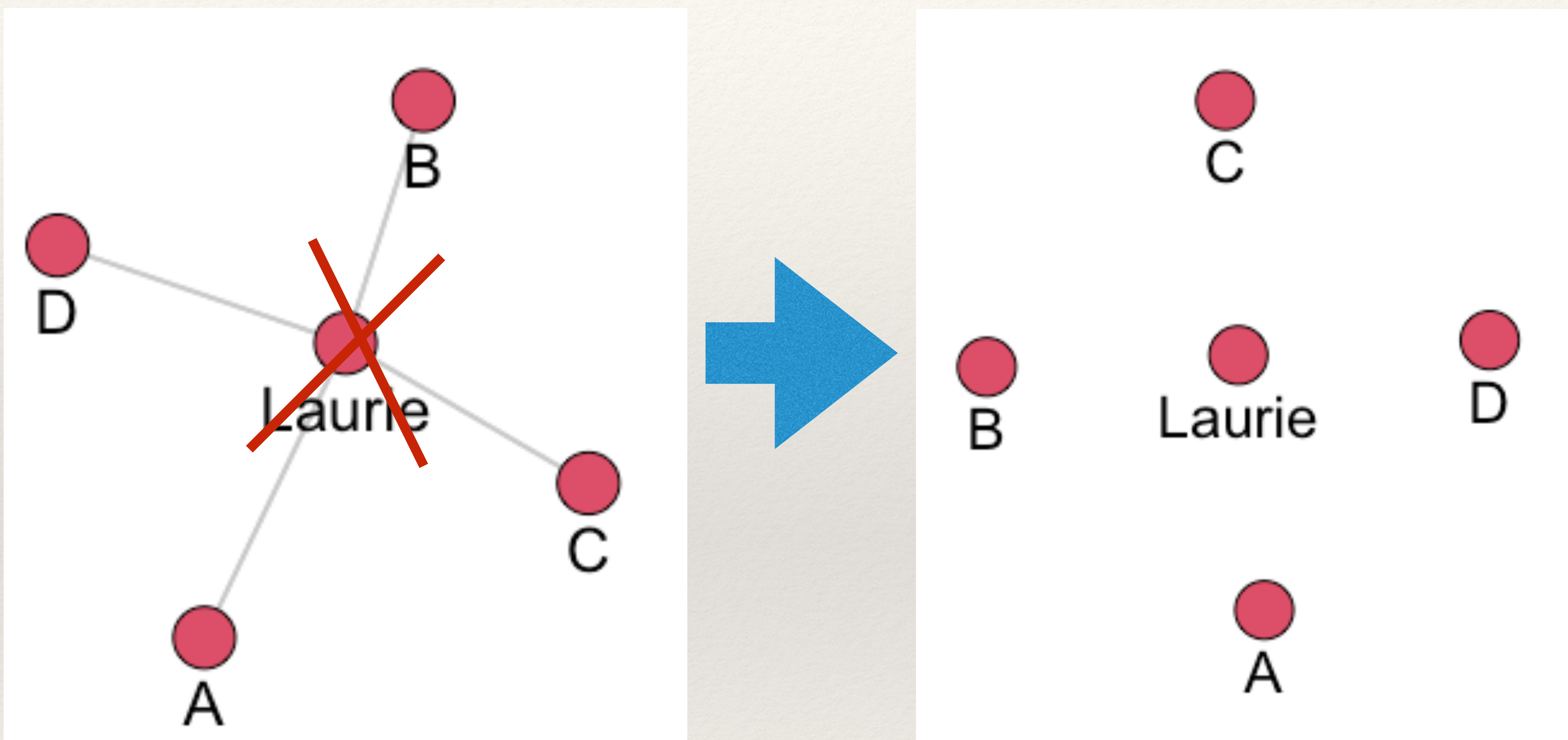
*It is **vulnerable**…*

Sudden Death Of Aunt Creates Rupture In Family Gossip Pipeline

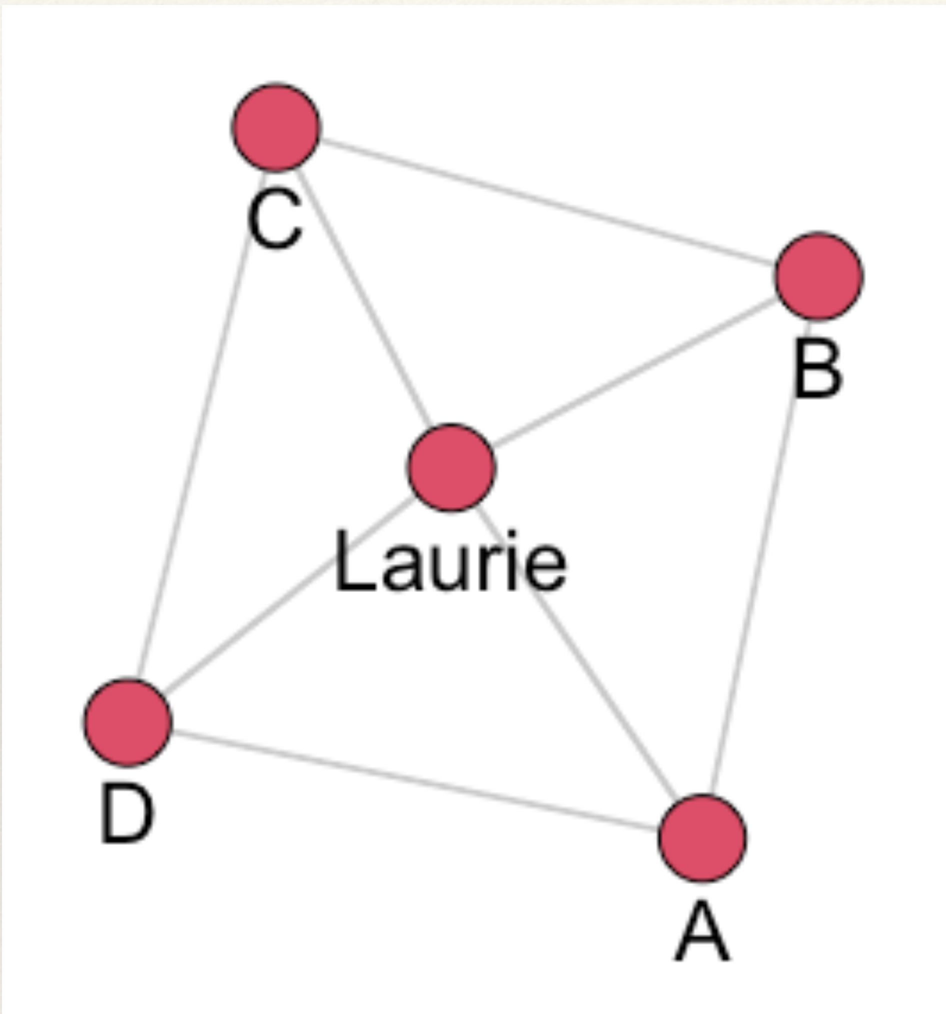


Sudden Death Of Aunt Creates Rupture In Family Gossip Pipeline

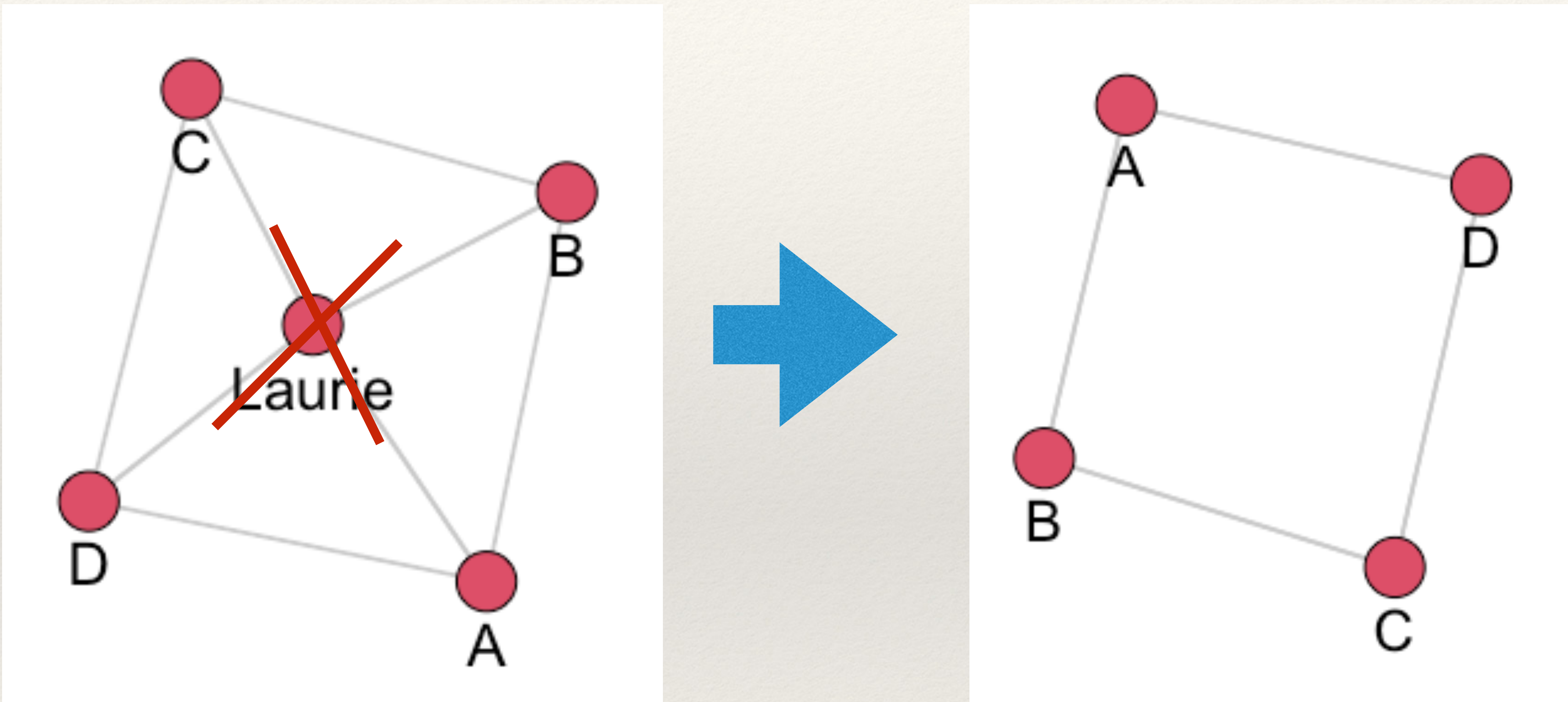


*Why is it is **vulnerable**?*

Sudden Death Of Aunt Creates Rupture In Family Gossip Pipeline



Sudden Death Of Aunt ~~Creates~~ ~~Rupture~~ In Family Gossip Pipeline



Why is it <u>not</u> is ***vulnerable****?*

The Point!

- These are topics that are inherently **relational**.
- *How do we go from theory to analysis?*

REMEMBER THIS?

- REMEMBER YOUR RESEARCH METHODS:
    - Conceptualization and Operationalization!
- Network science **conceptualizes** theoretical concepts that are inherently relational.
    - *Can you think of a relational theoretical concept?*
- Network research **operationalizes** theoretical constructs by drawing on the formal properties of graphs.
    - *Can you think of how that relational concept may be operationalized?*

Basic Data Elements

What do networks "look like"?

Basic Data Elements

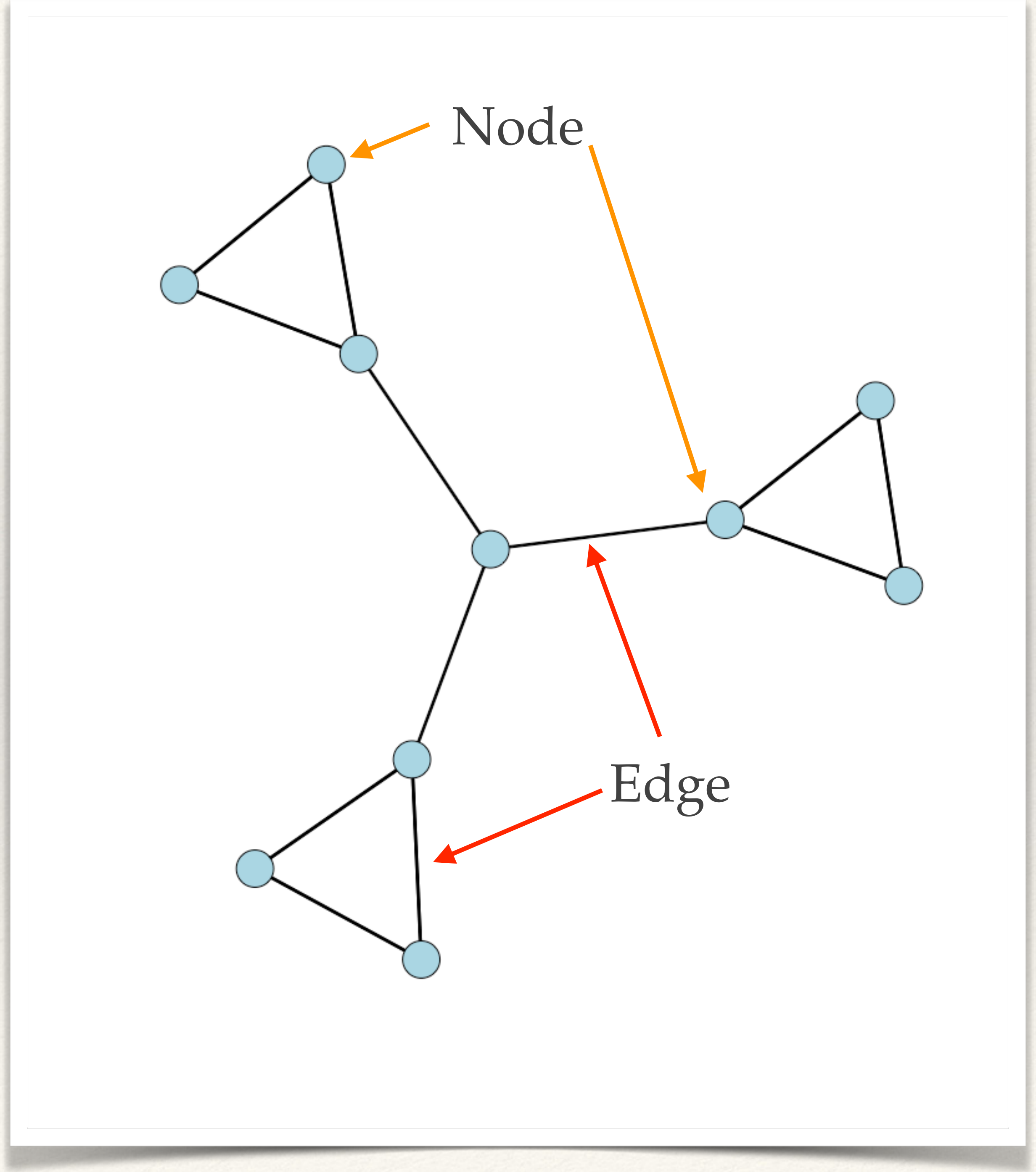
- Network (relational) data represent:
  - **Connections** (aka ties, arcs, edges, lines, ties) among,
  - **Entities** (aka nodes, vertices, actors, points, dots).
- I will use *node* to mean **entities** and *edge* to mean **connections.**

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?*

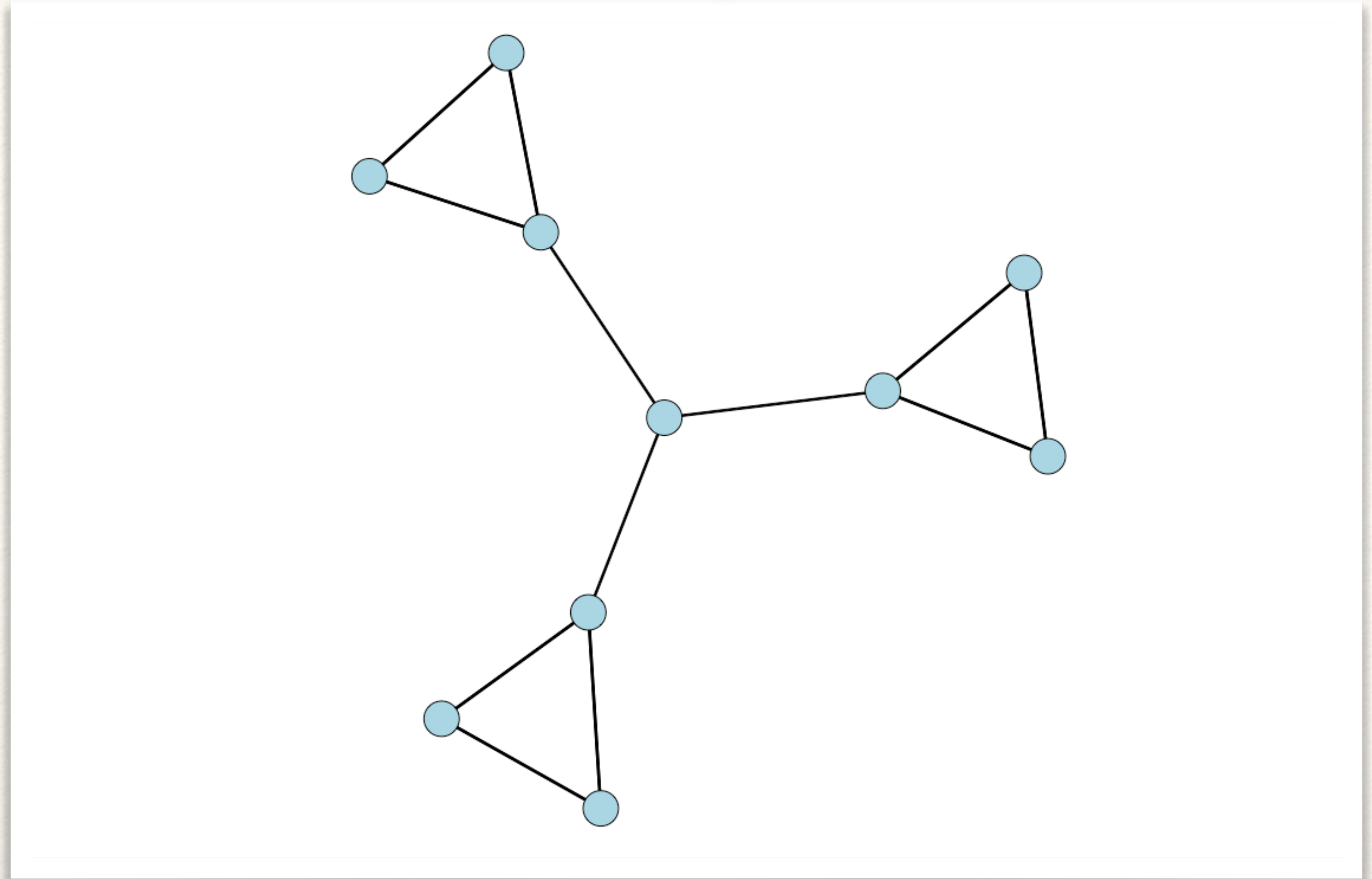
Basic Data Elements

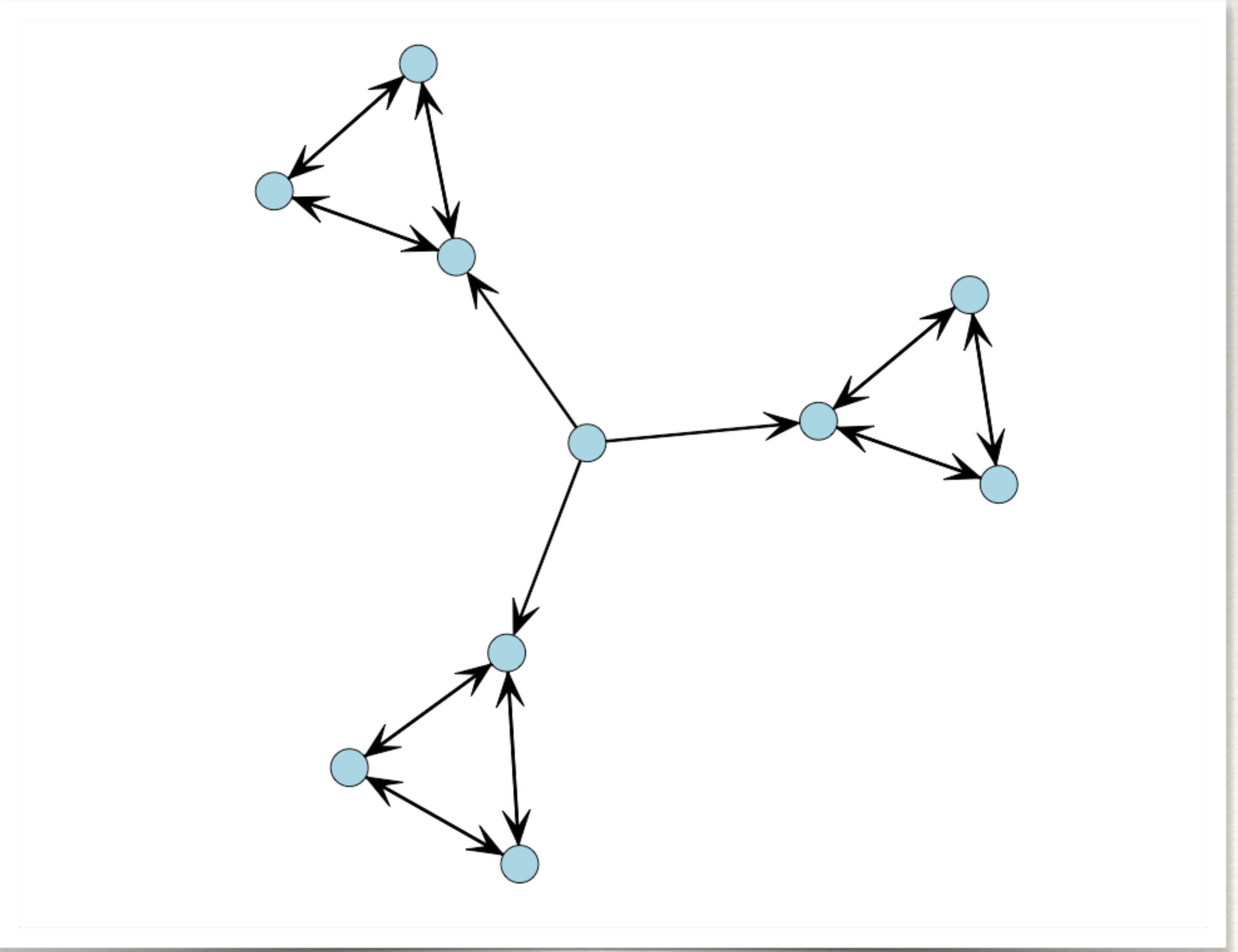
- On a graph, nodes are represented by *points* and edges are represented by *lines*.

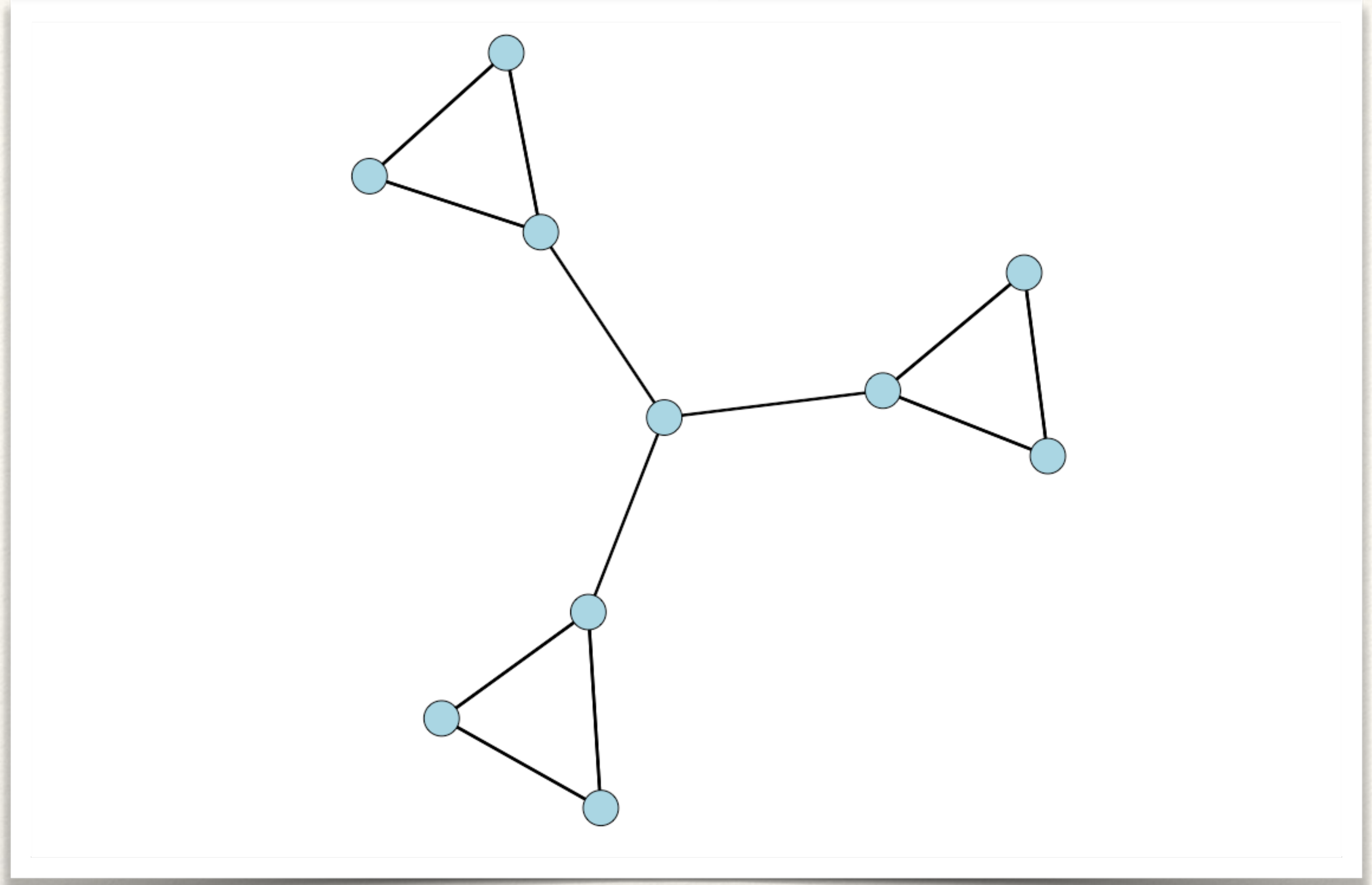


Basic Data Elements

- Edges can be:
  - Directed or Undirected.

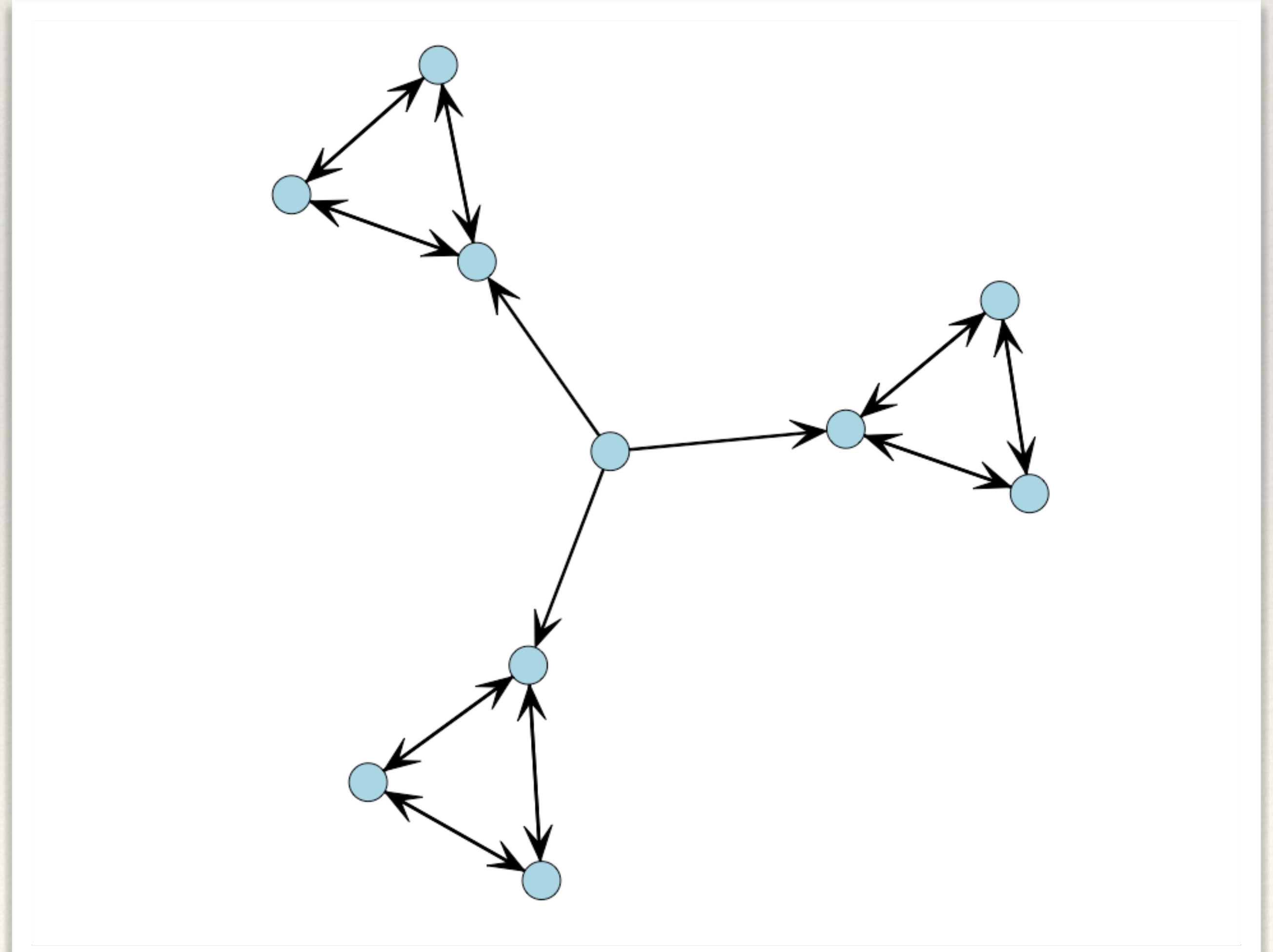






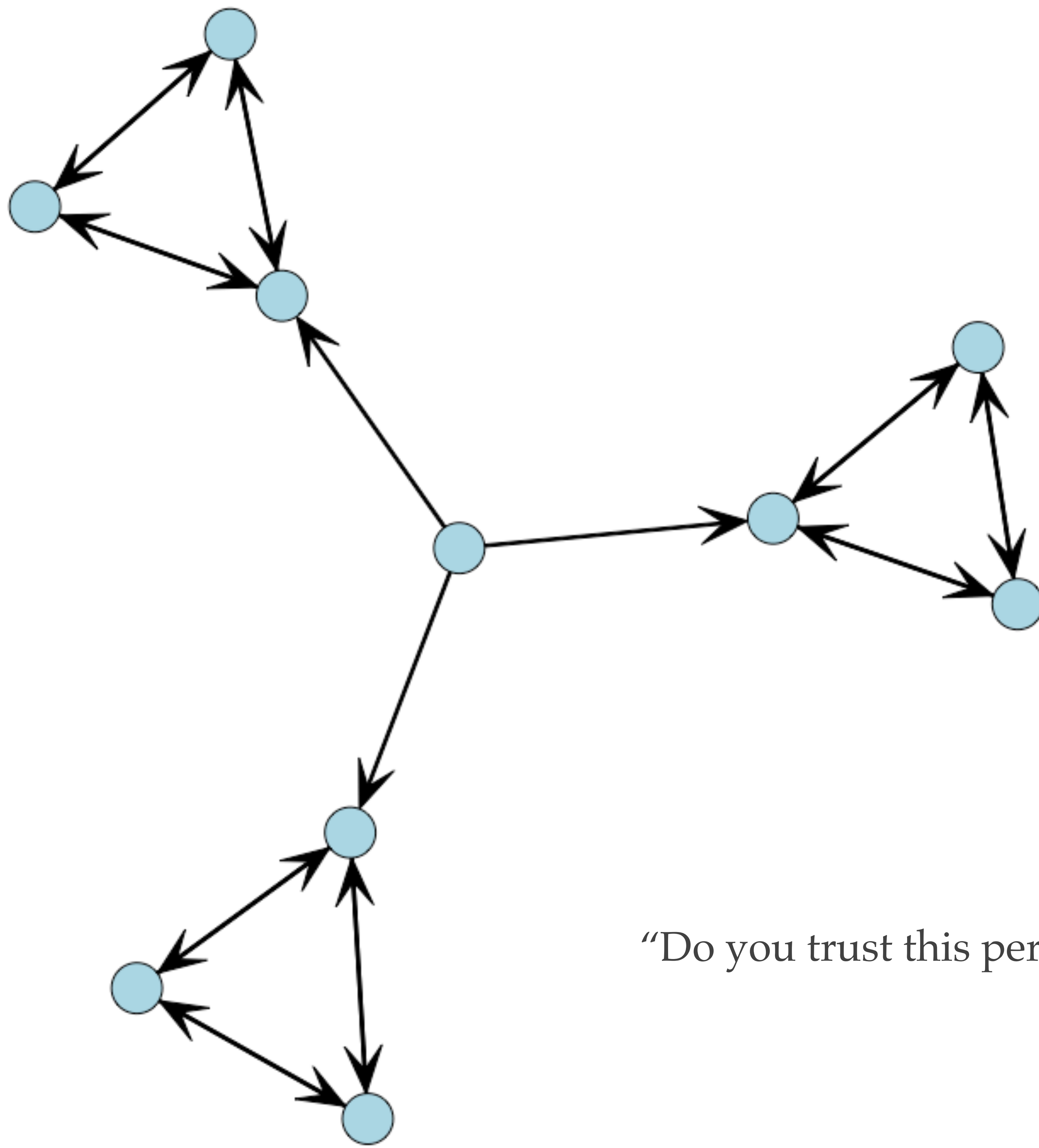
Suppose the edges measure communication…

How are these structures different?

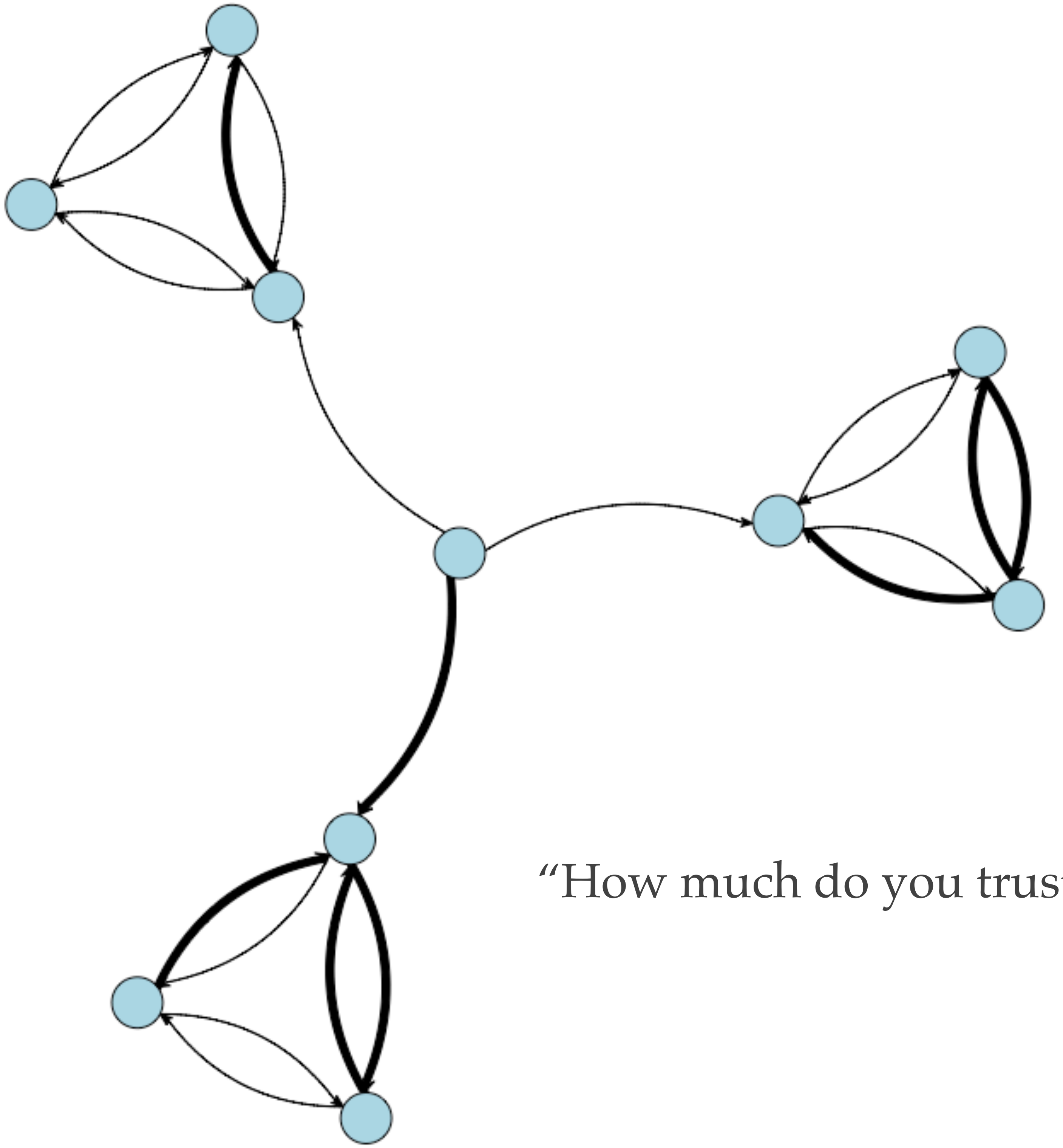


Basic Data Elements

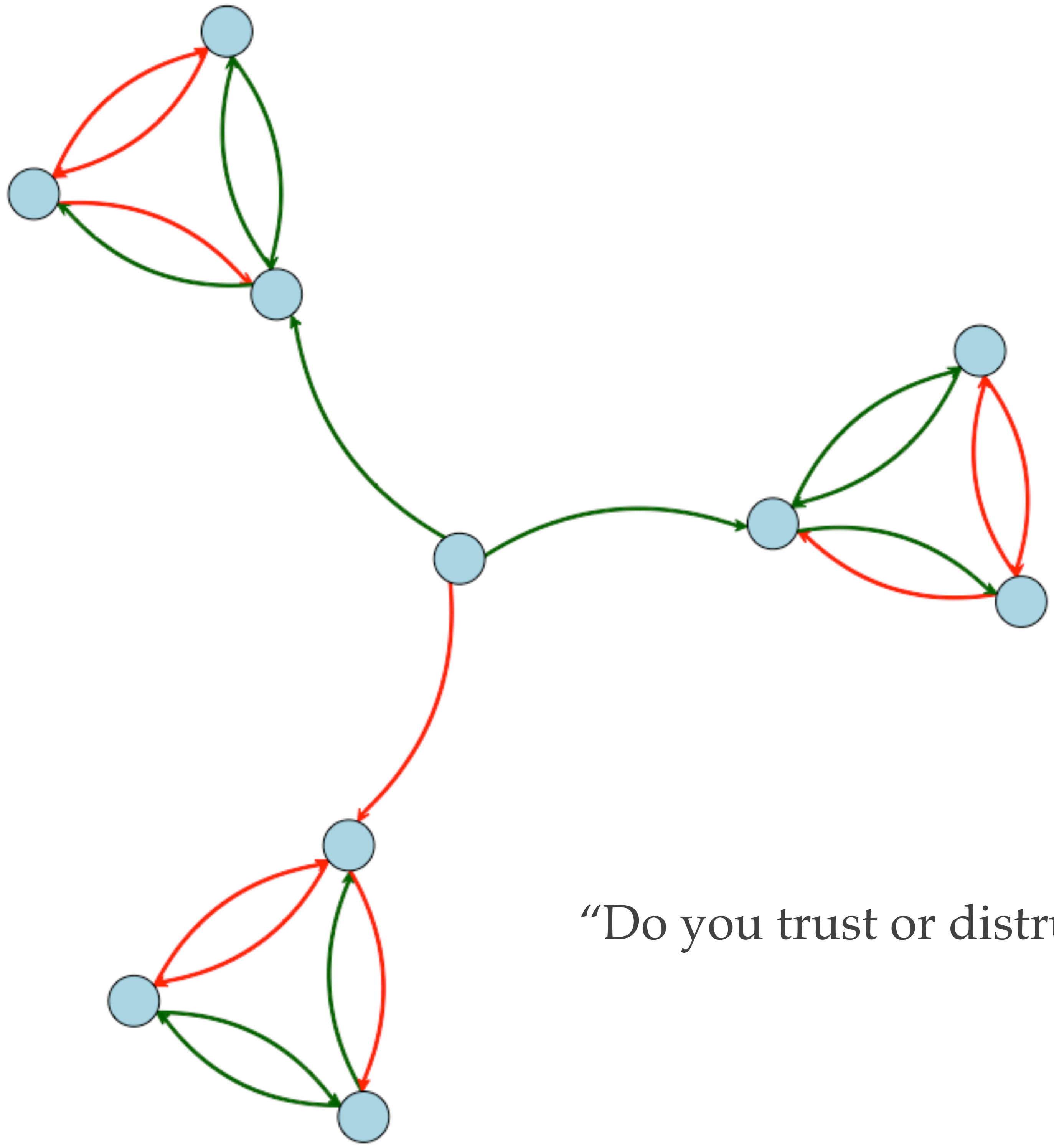
- **Edges** can be:
  - Binary (0/1; present/absent); Valued Integers (0/1/2…); Continuous Weights (0.24/1.76/…); Signed (+/-).



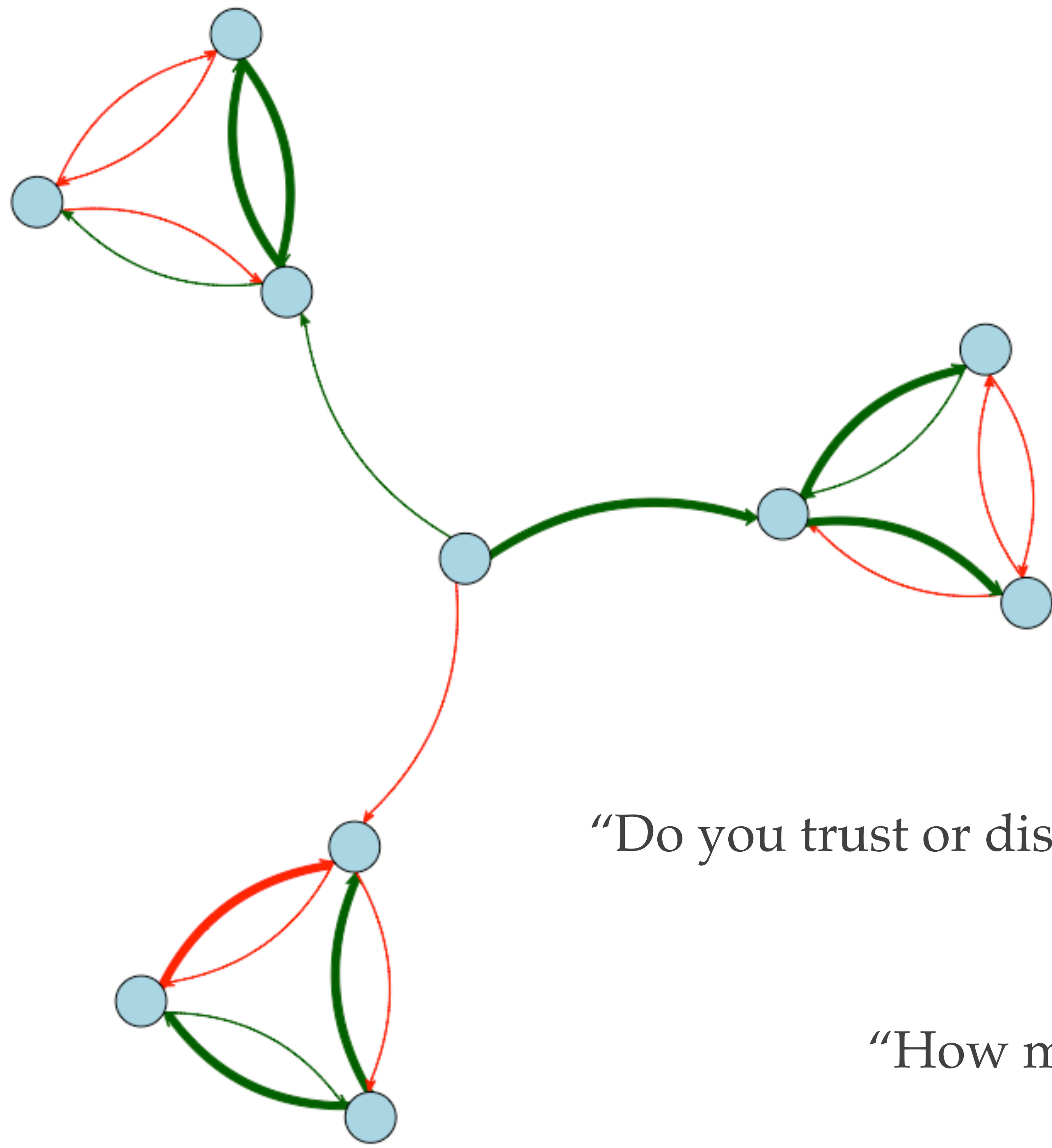
“Do you trust this person?”



"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, attitudes)

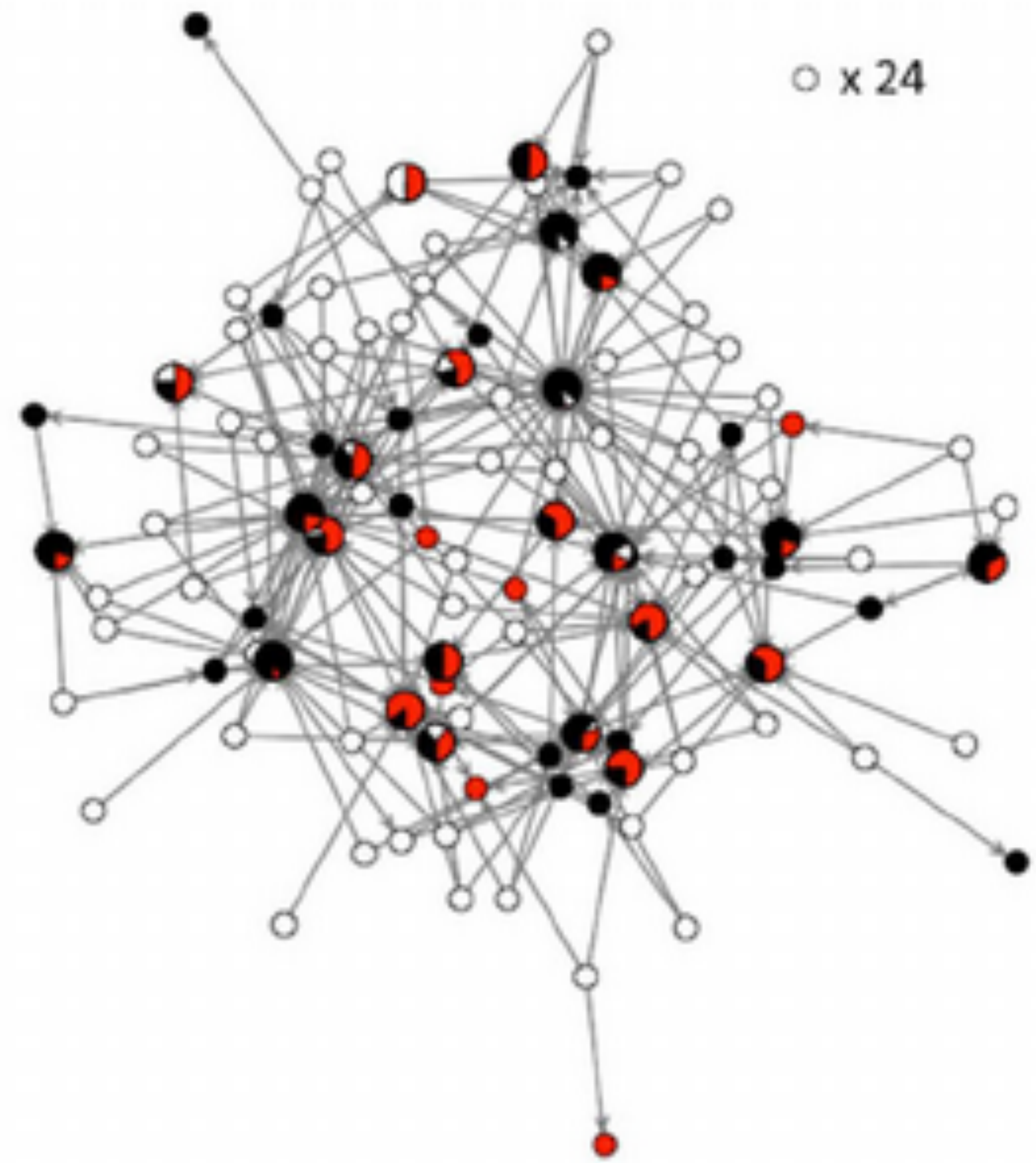
ARTICLE

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



(a)

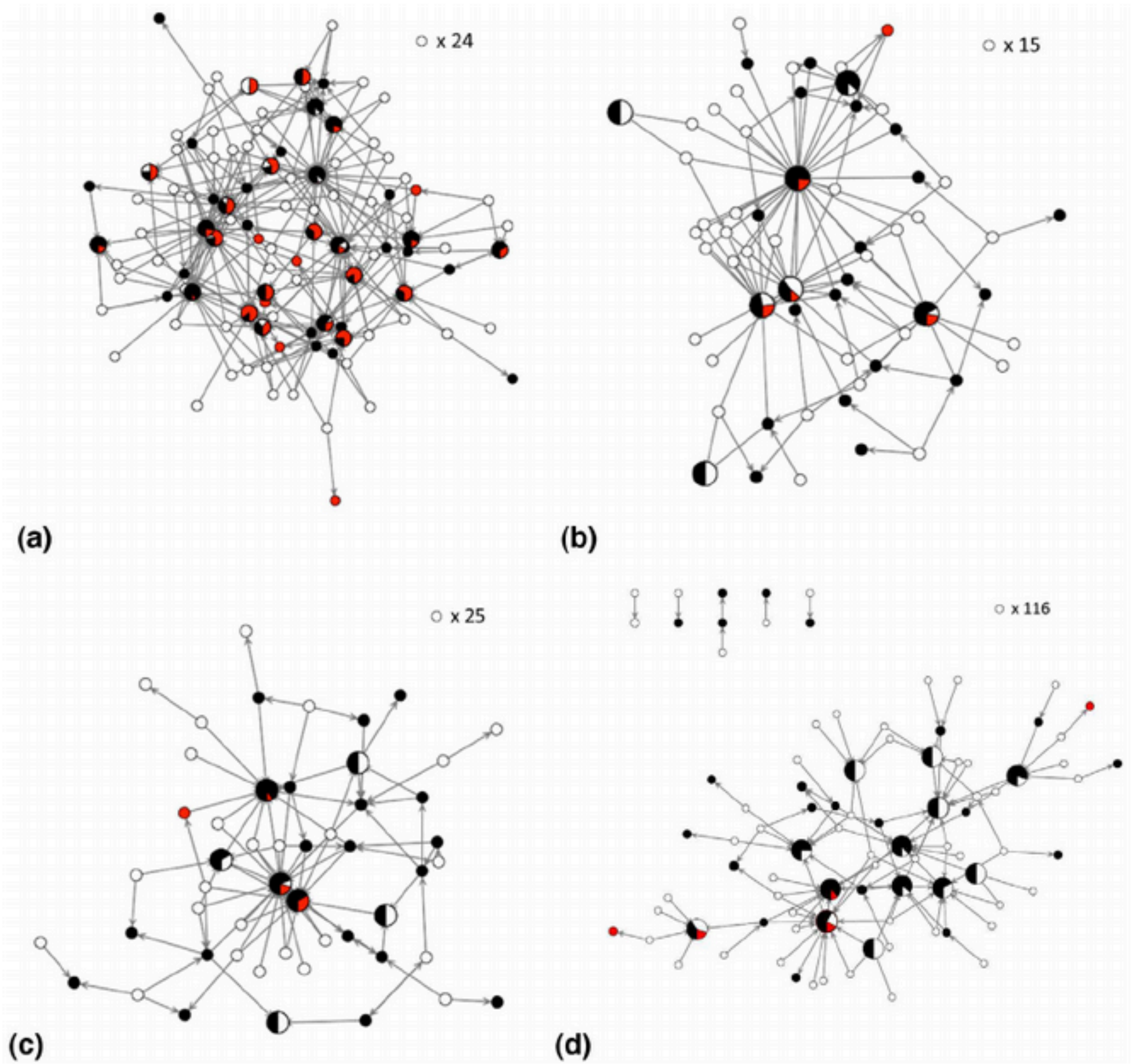
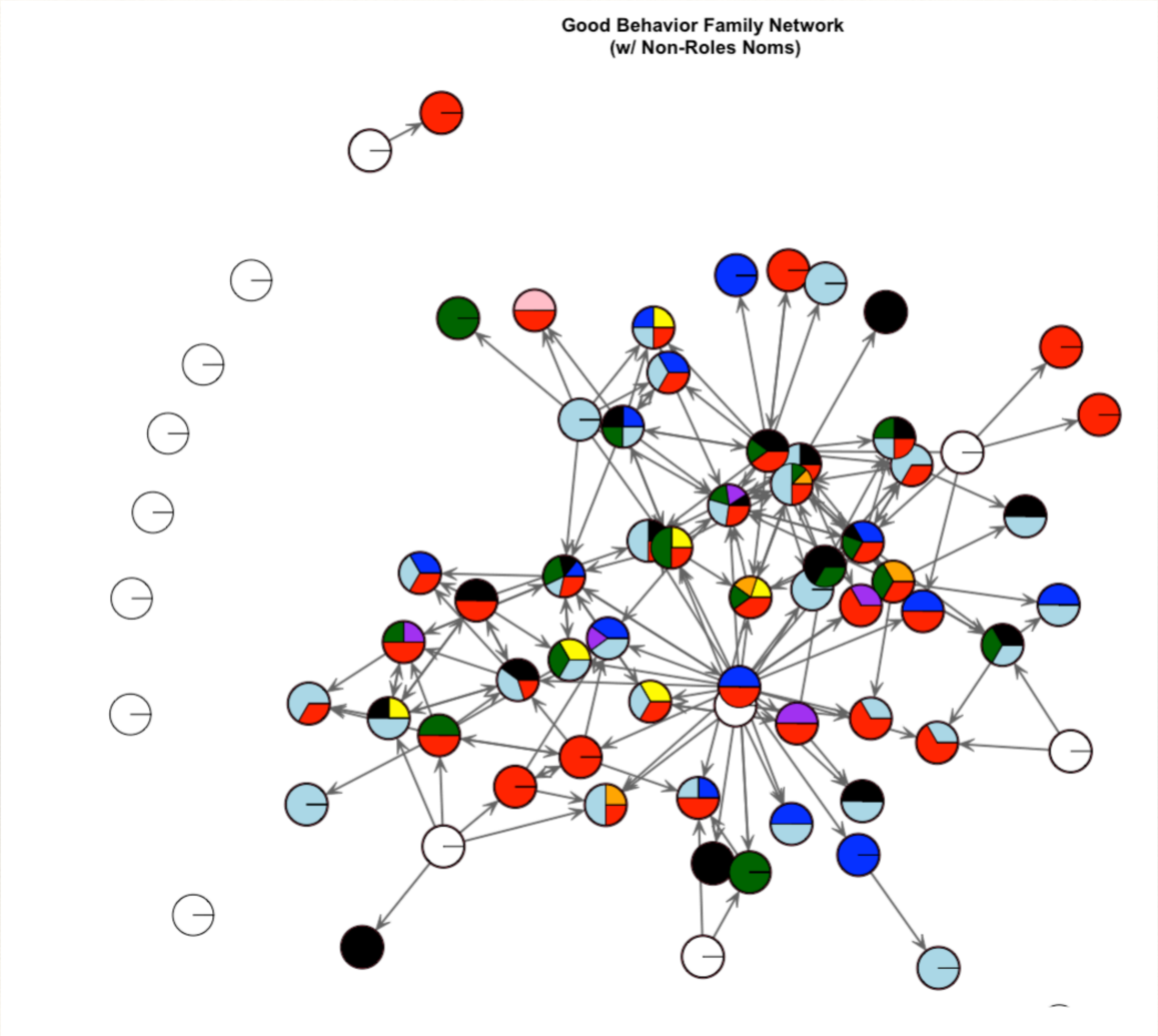


FIGURE 1 Balance of positive, neutral, and negative ties in the status networks of (a) Unit 1, (b) Unit 2, (c) Unit 3, and (d) Men's Unit [Color figure can be viewed at wileyonlinelibrary.com]

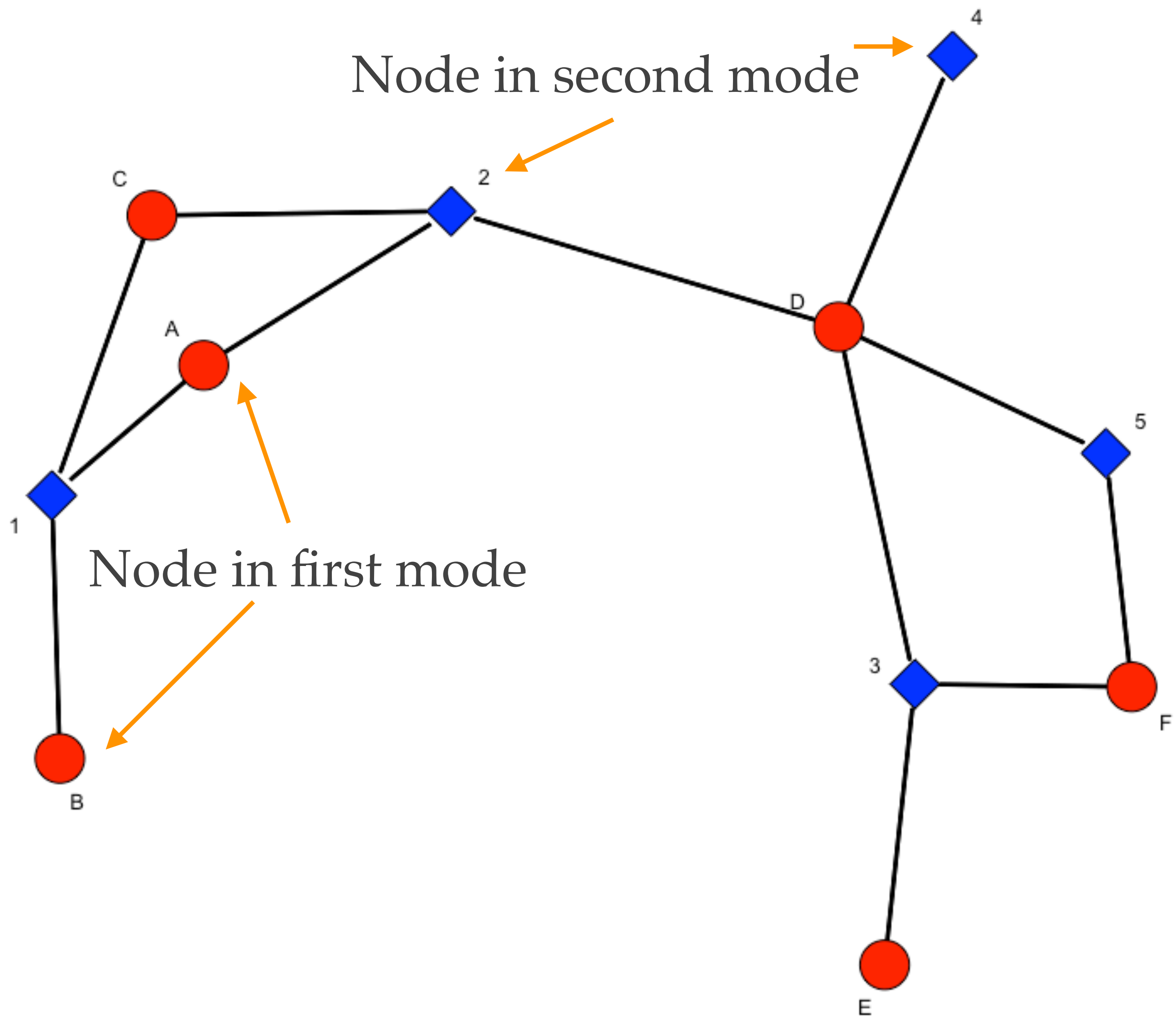
Notes: Nodes sized by indegree, isolate frequencies listed in top-right of each graph, and pie charts reflect proportion of incoming nominations that are positive [black], neutral [white], and negative [red].

Family Role Nominations among Incarcerated Women



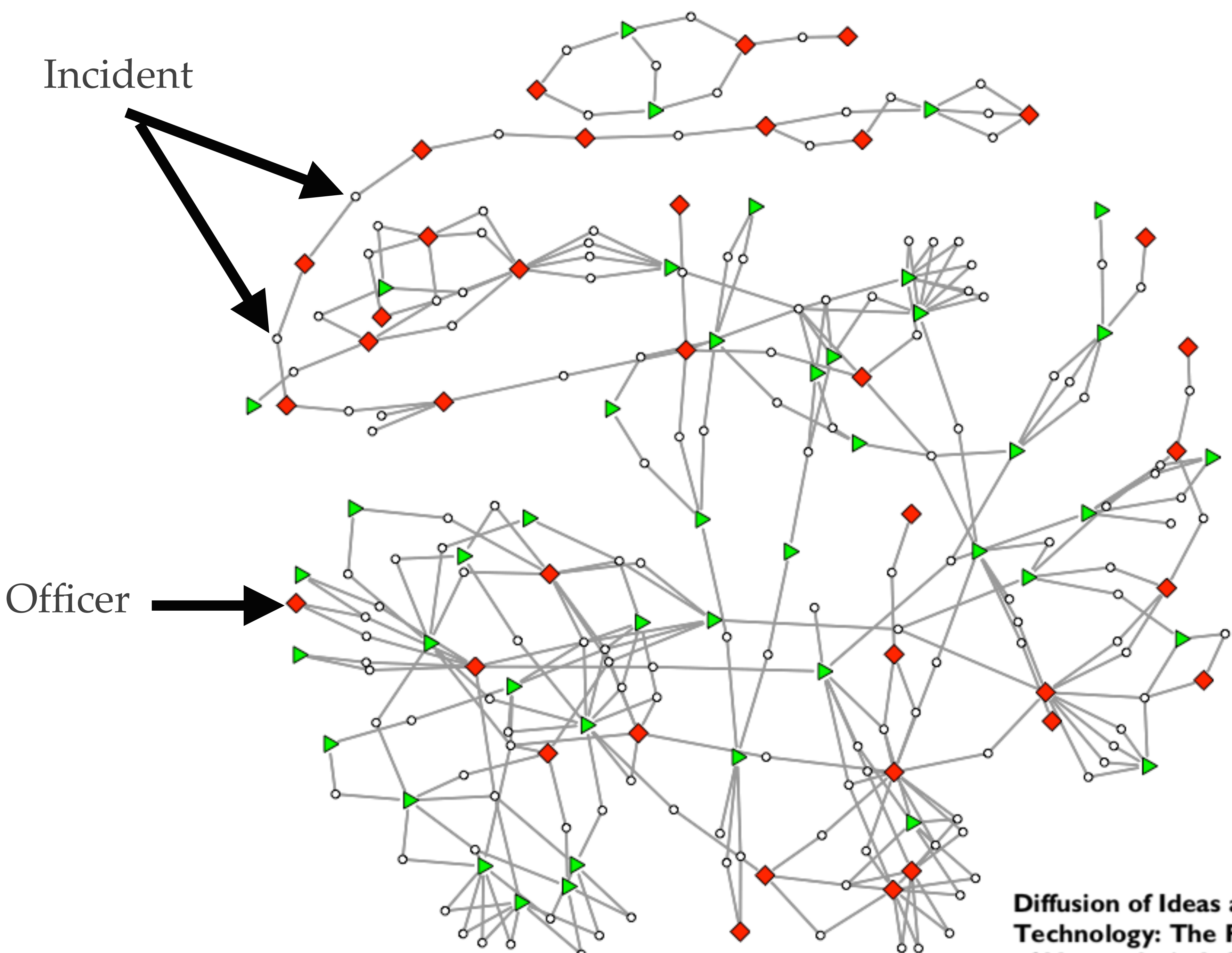
Basic Data Elements

- *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
4
C
2
D
A
5
1
Node in first mode
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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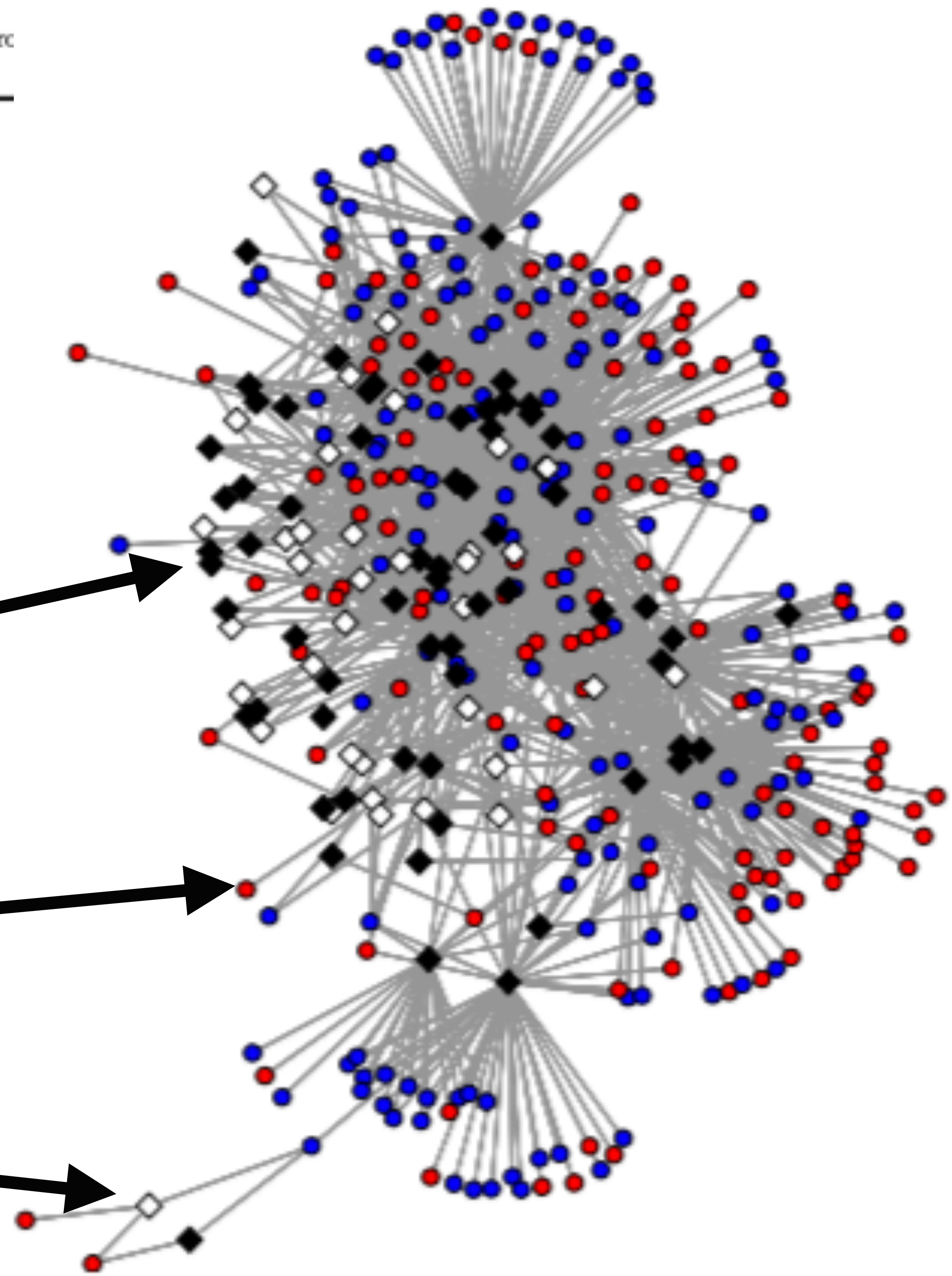
Am J Crim Just (2018) 43:197–221
DOI 10.1007/s12103-017-9395-5

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]

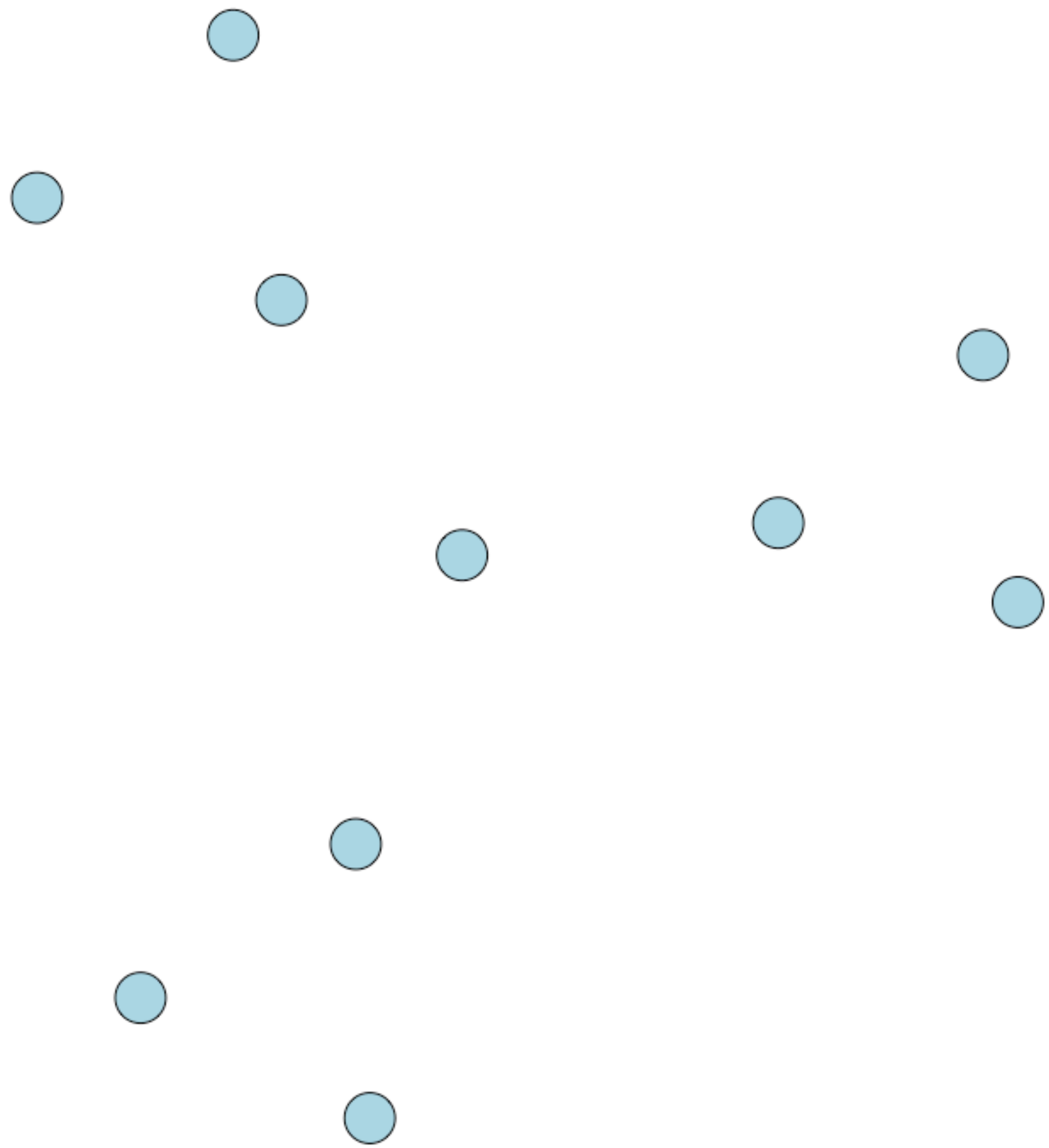
B: Plot of 291 Signers of 101 Bills in the Senate

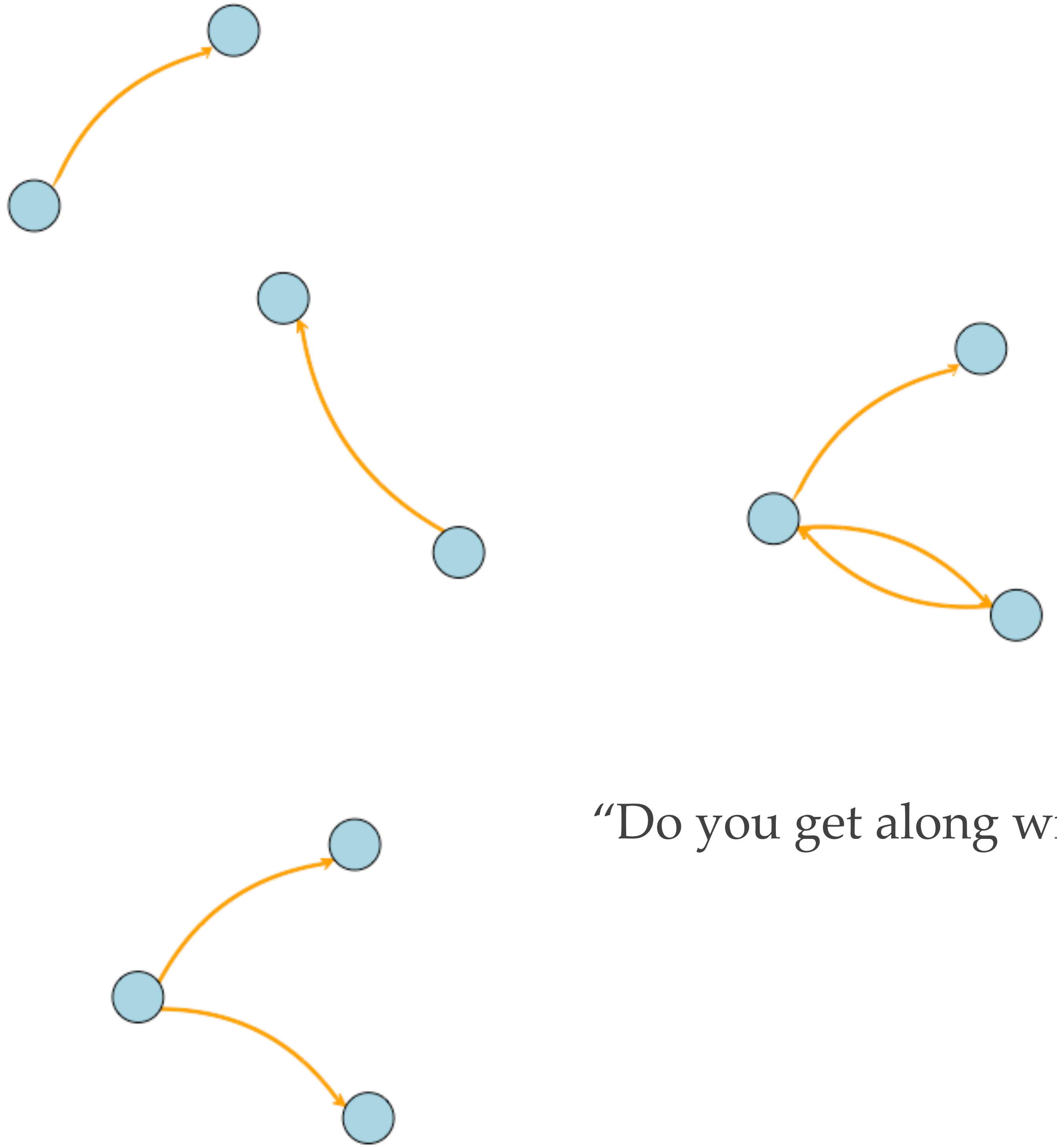


Democrats = Blue; Republicans = Red; CC Bills = Black; NCC Bills = White

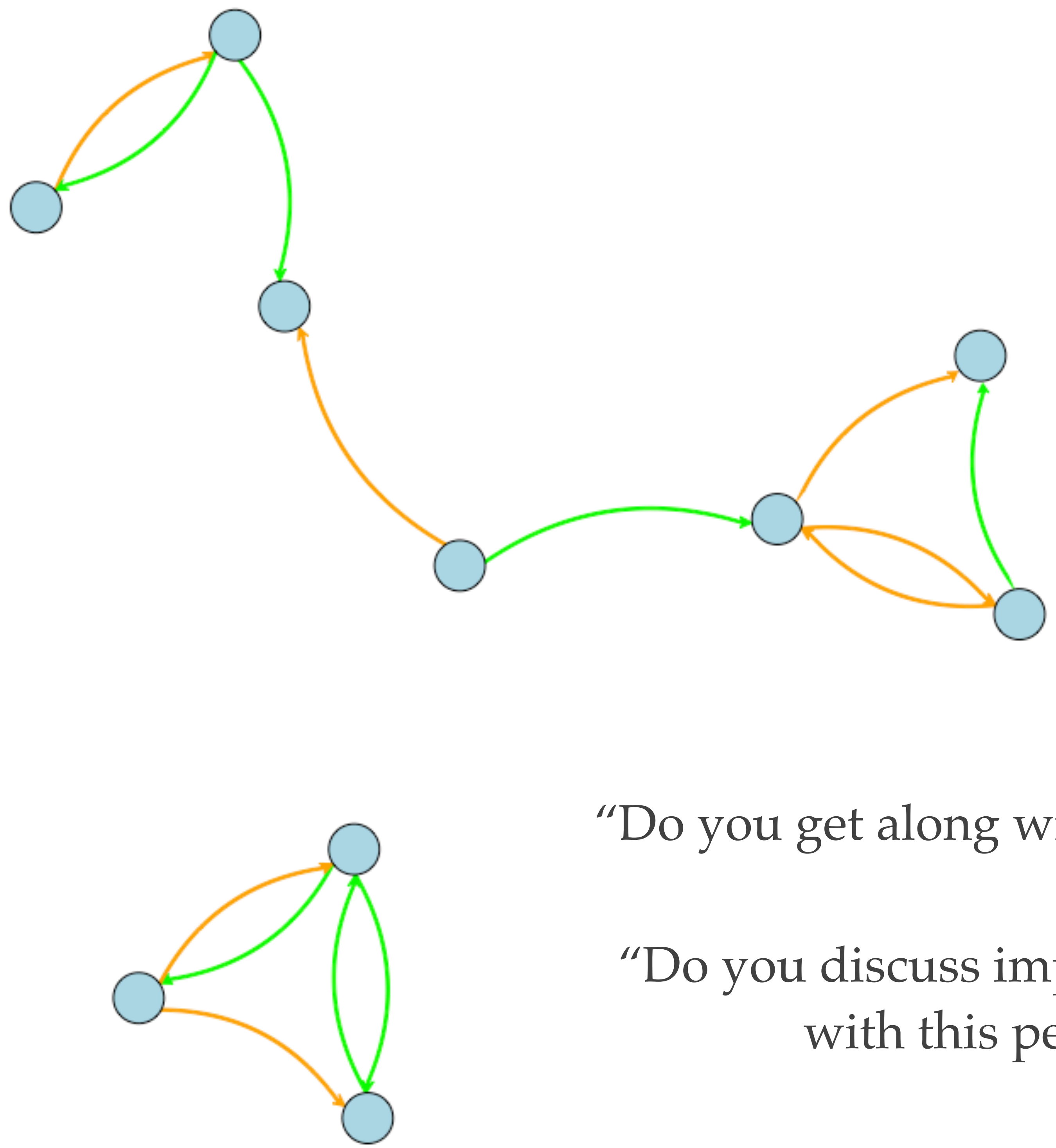
Basic Data Elements

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



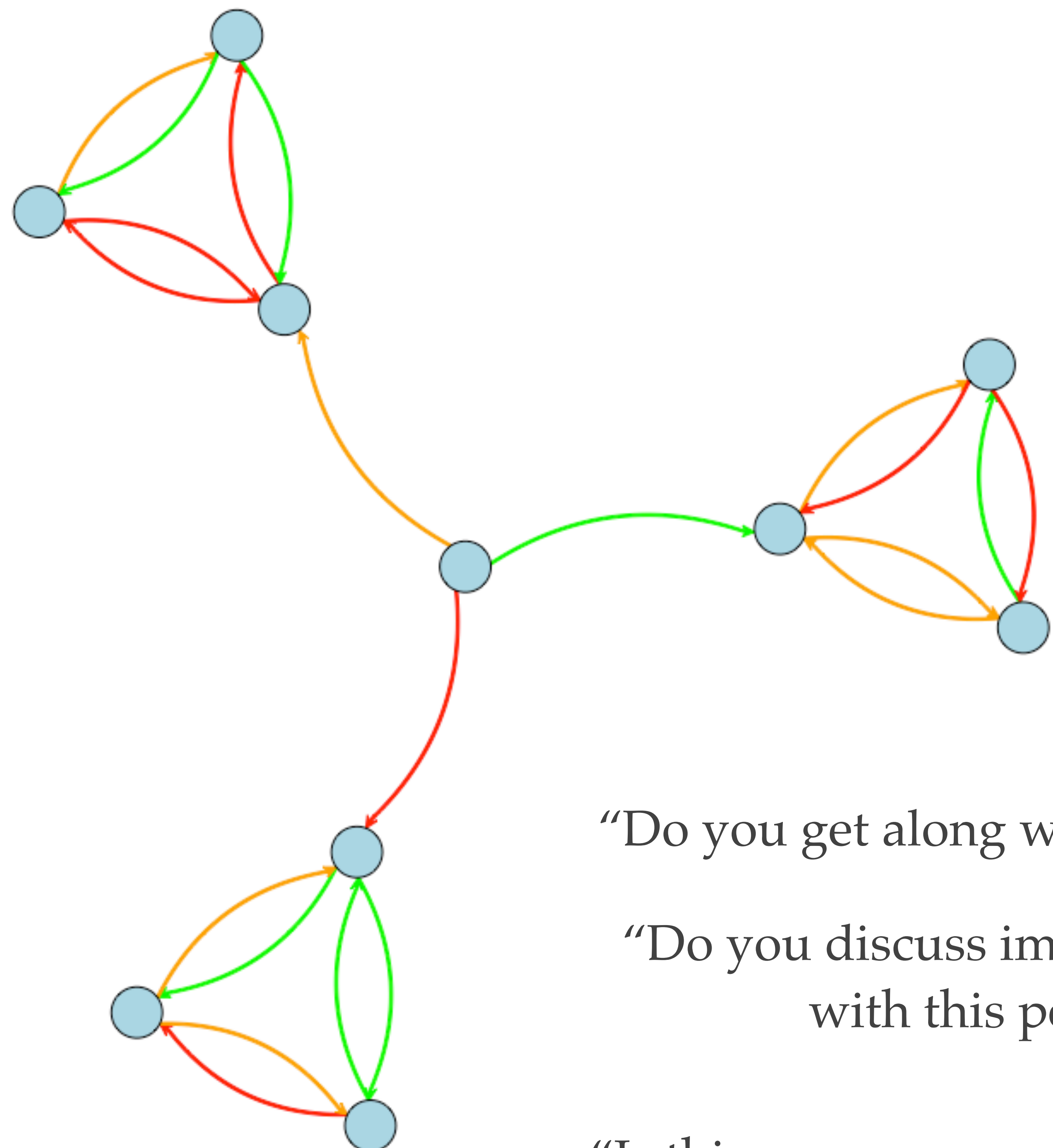


"Do you get along with this person?"



“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?”

Summary

- *Relational* data can take many different forms and be represented many different ways.

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
        - <u>Why</u>?-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 to share personal information with?"
  - Free response
    - "Who are the people in this prison that you trust with person information about you?"

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…"
  - *What does this mean?*

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?"

Questions?

Break!

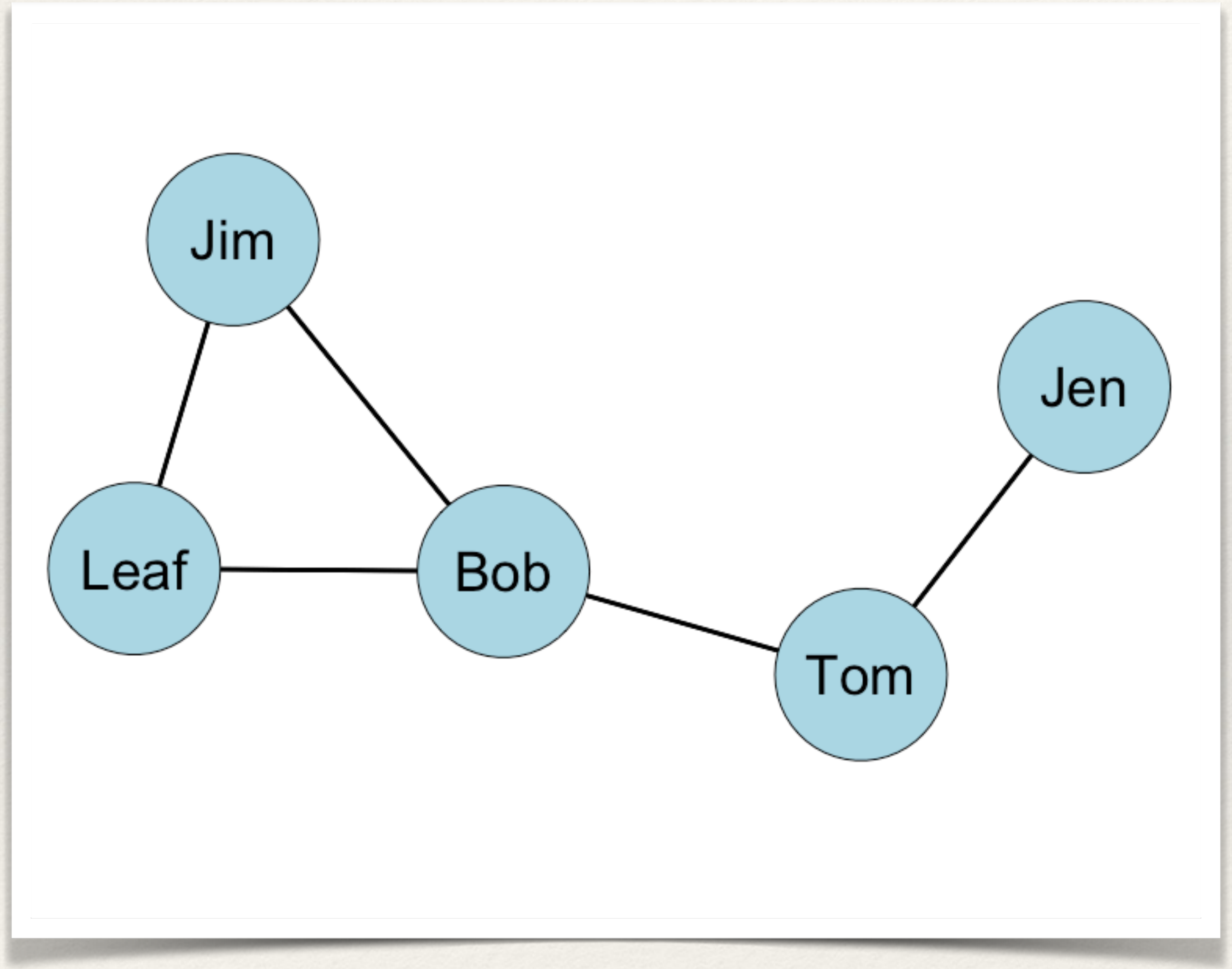
Representing Networks with Graphs and Matrices

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

Sociometric Notation

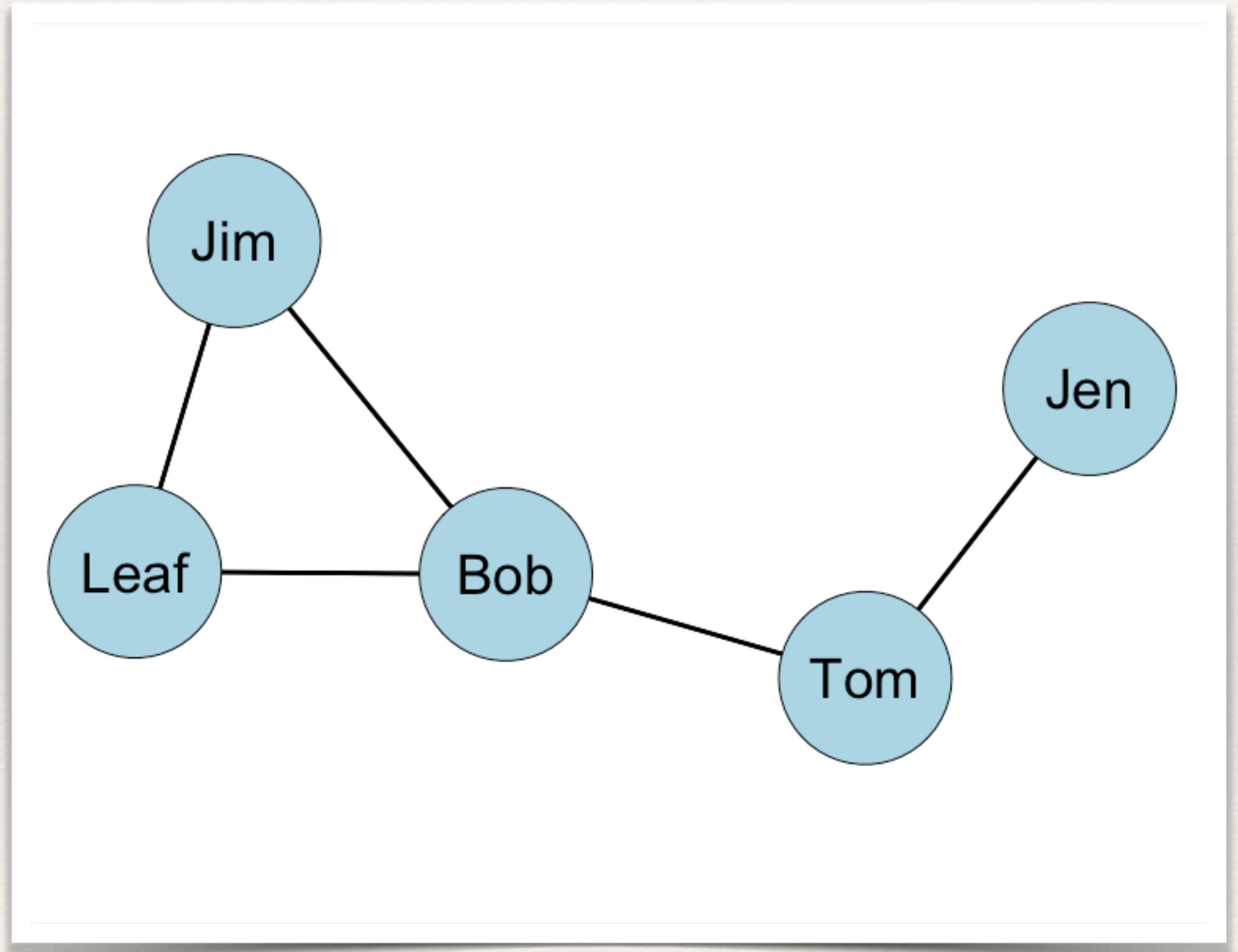
- For a set of relations, ***X***, we can define a matrix which represents these relations.
- We commonly use an *adjacency matrix*, where each node / vertex is listed on the row and the column.
- The i_{th} row and the j_{th} column X_{ij} records the value of a tie from i to j.
- In this approach,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

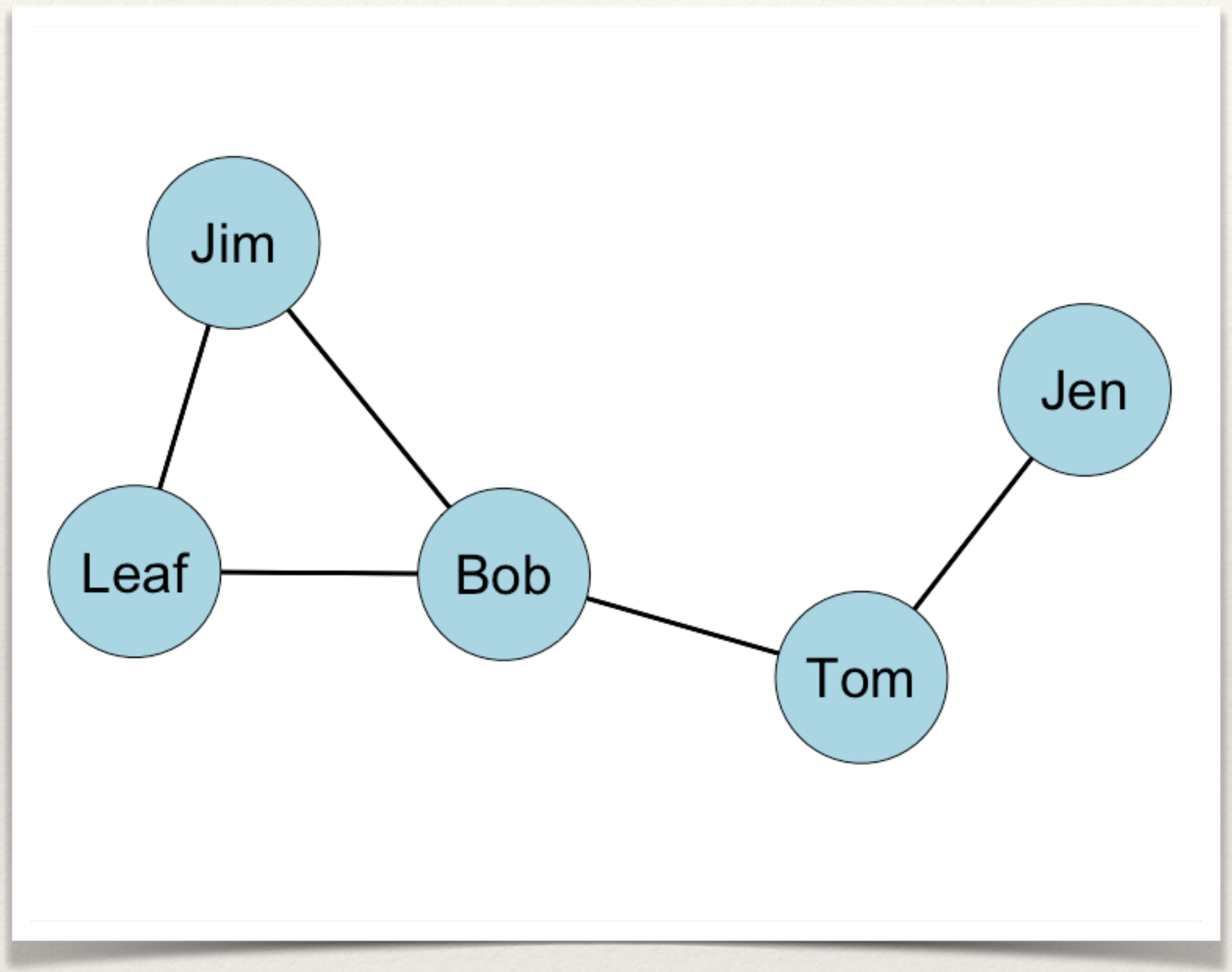


Graph or Sociogram

	Jen	Tom	Bob	Leaf	Jim
Jen					
Tom					
Bob					
Leaf					
Jim					

Adjacency Matrix or Sociomatrix

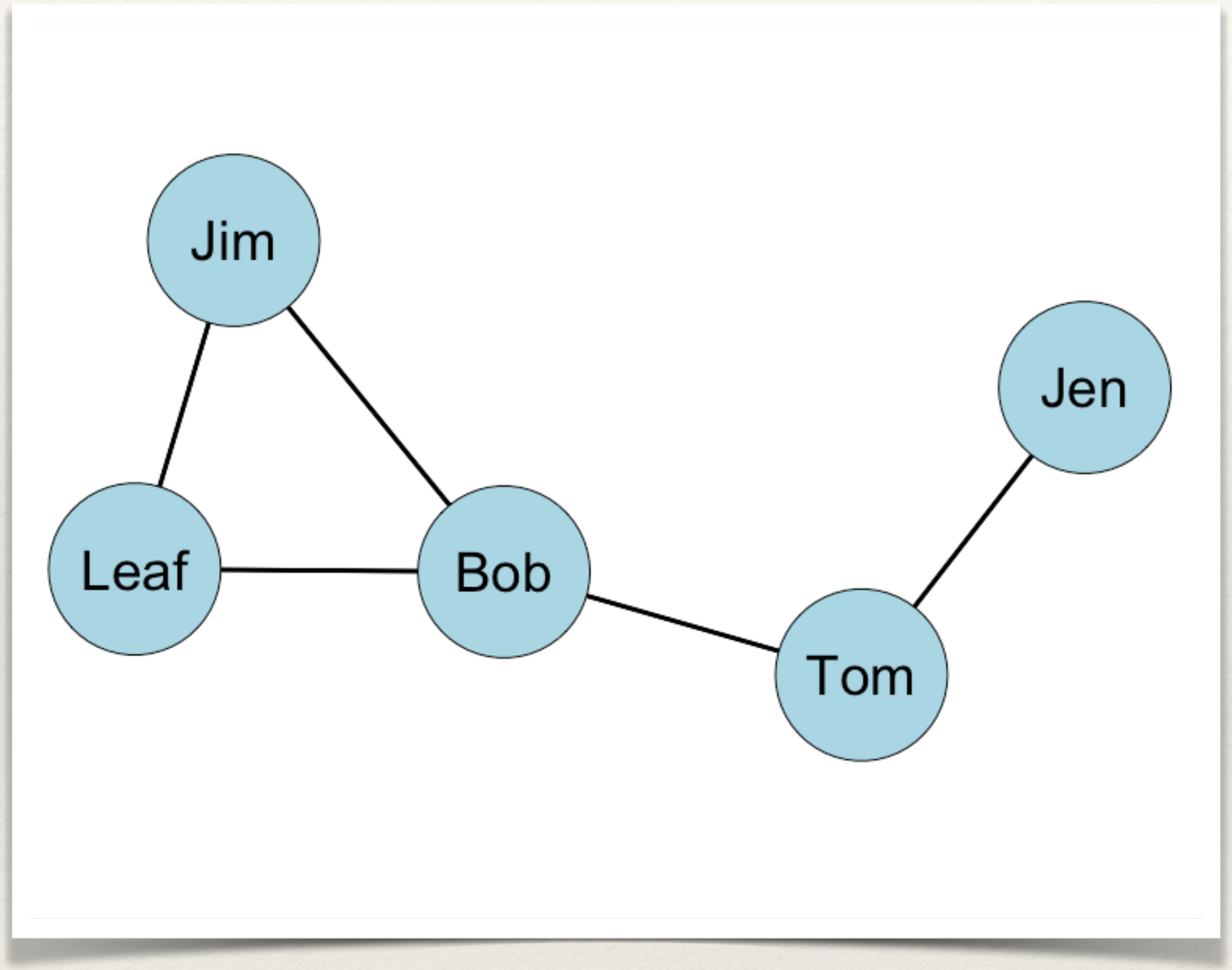
Example: Undirected, Binary Network



	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.

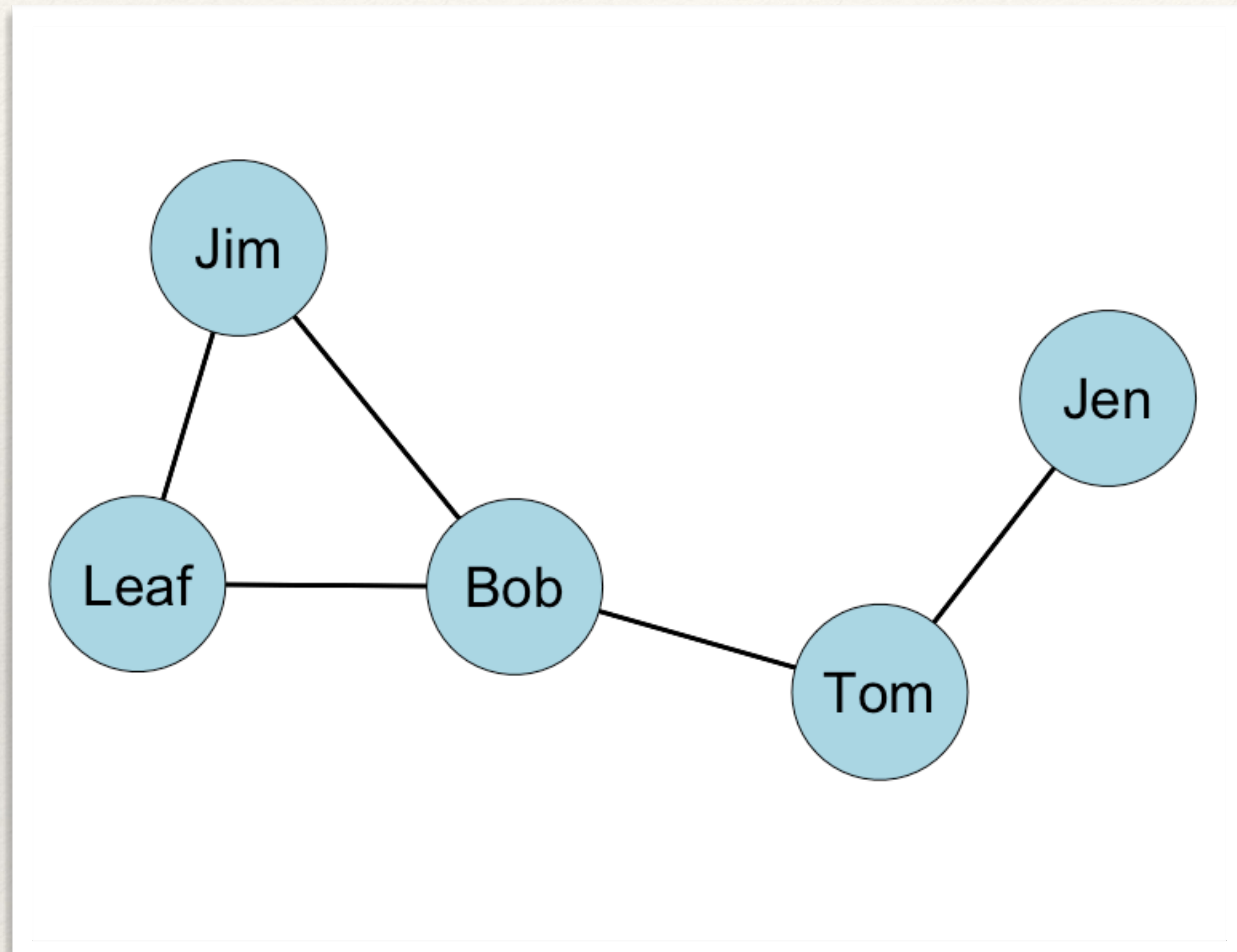
Example: Undirected, Binary Network



	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: $X_{12} = 1; X_{15} = 0$

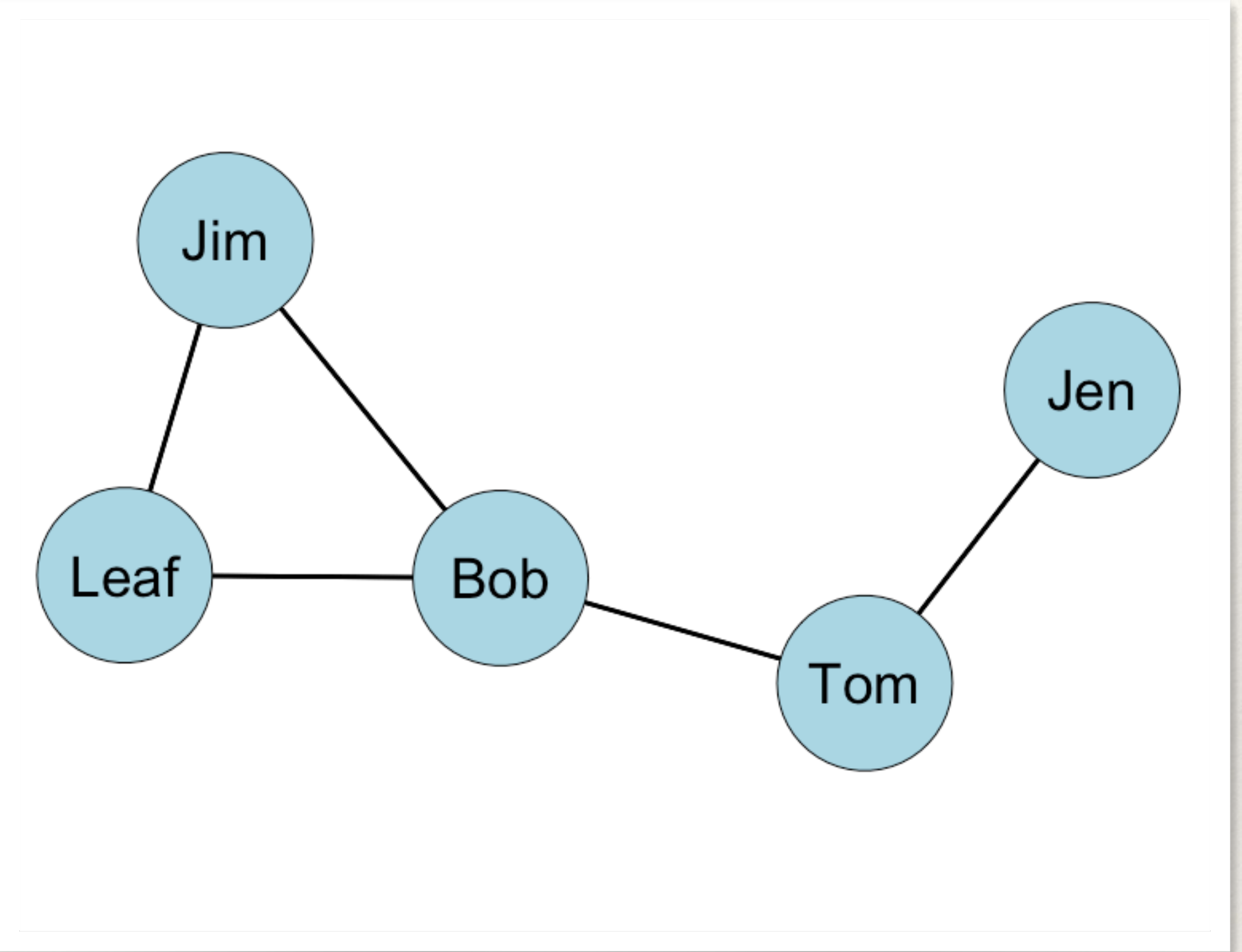
Example: Undirected, Binary Network



	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.

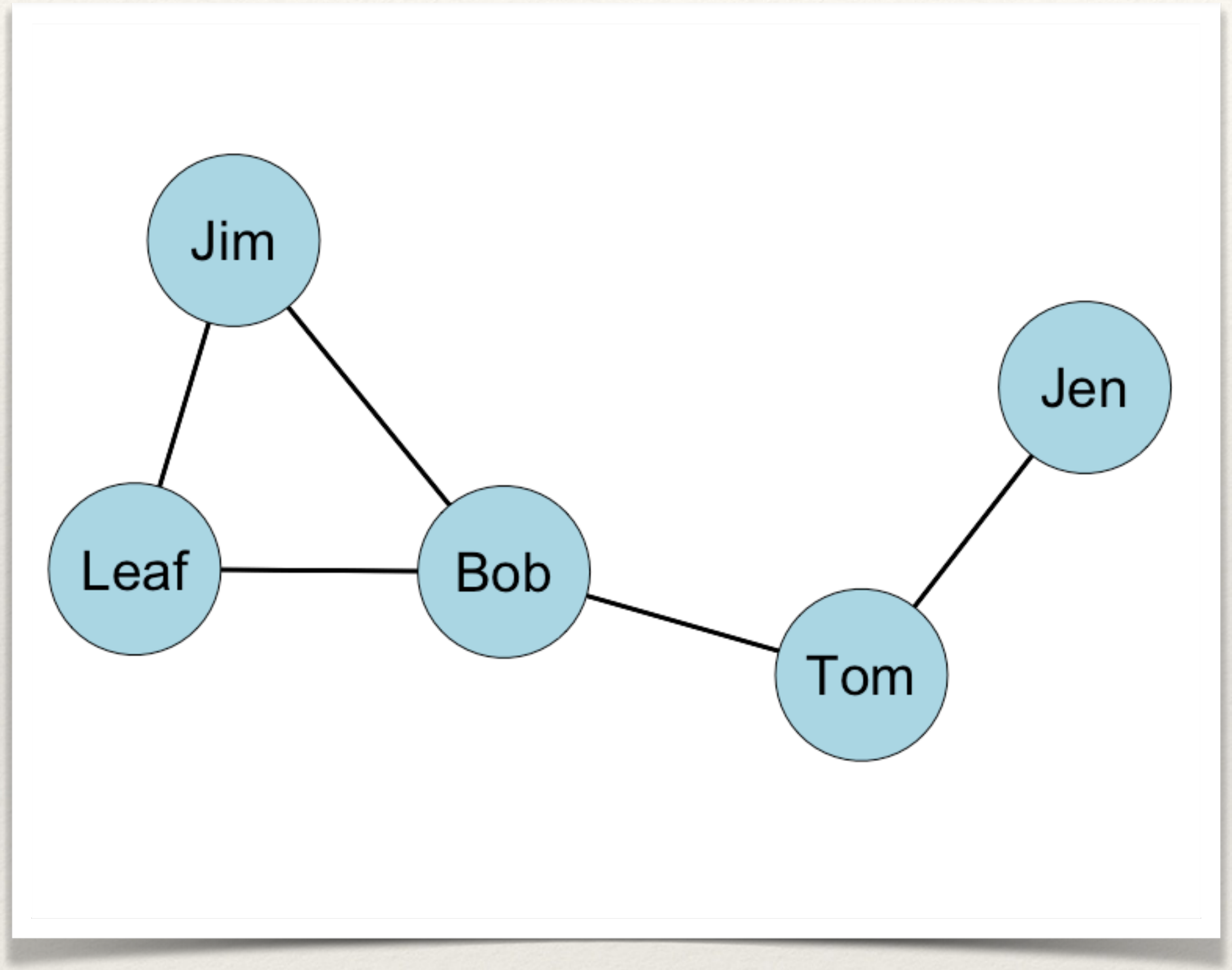
Example: Undirected, Binary Network



What does the rest of the matrix look like?

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

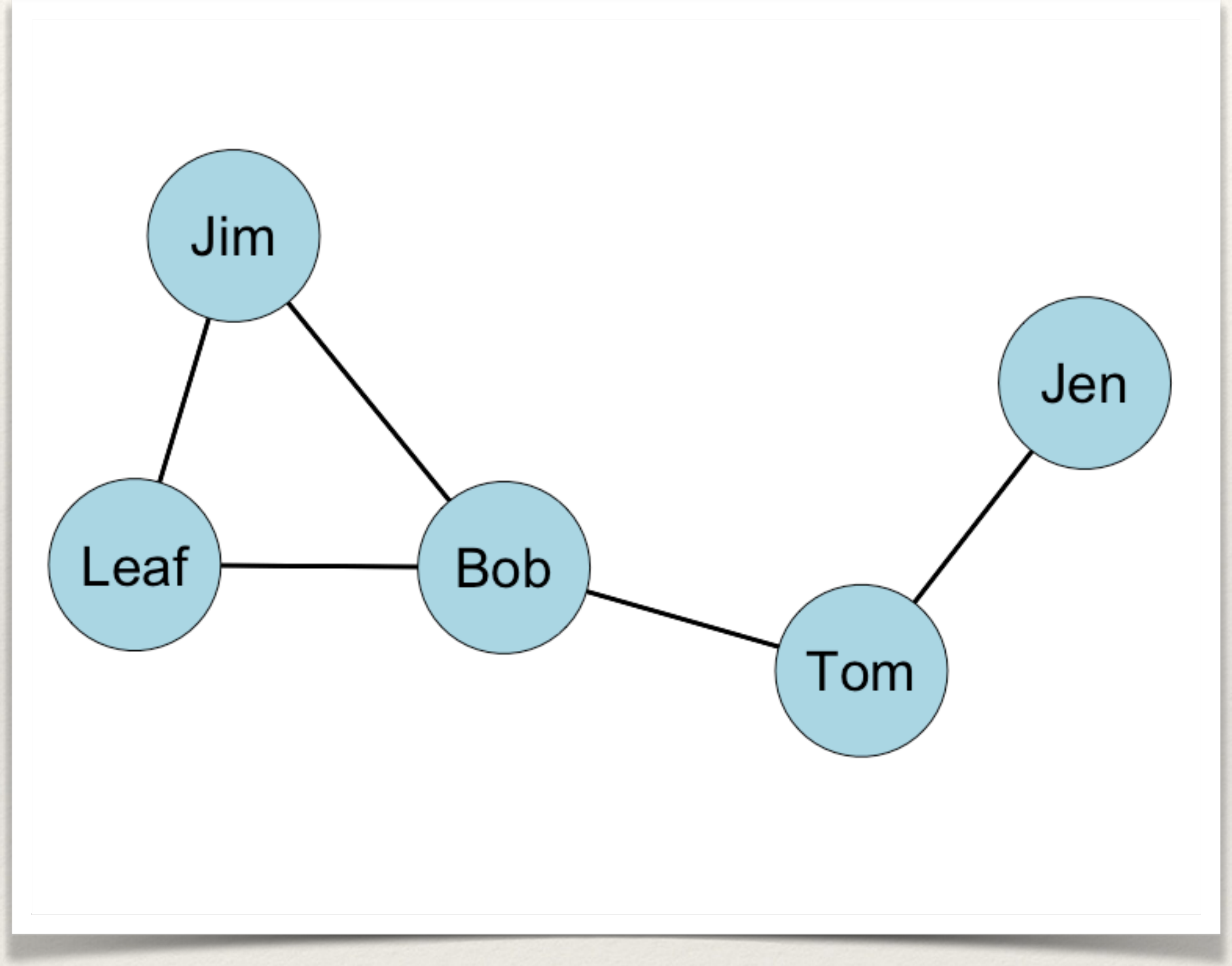
Example: Undirected, Binary Network



	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

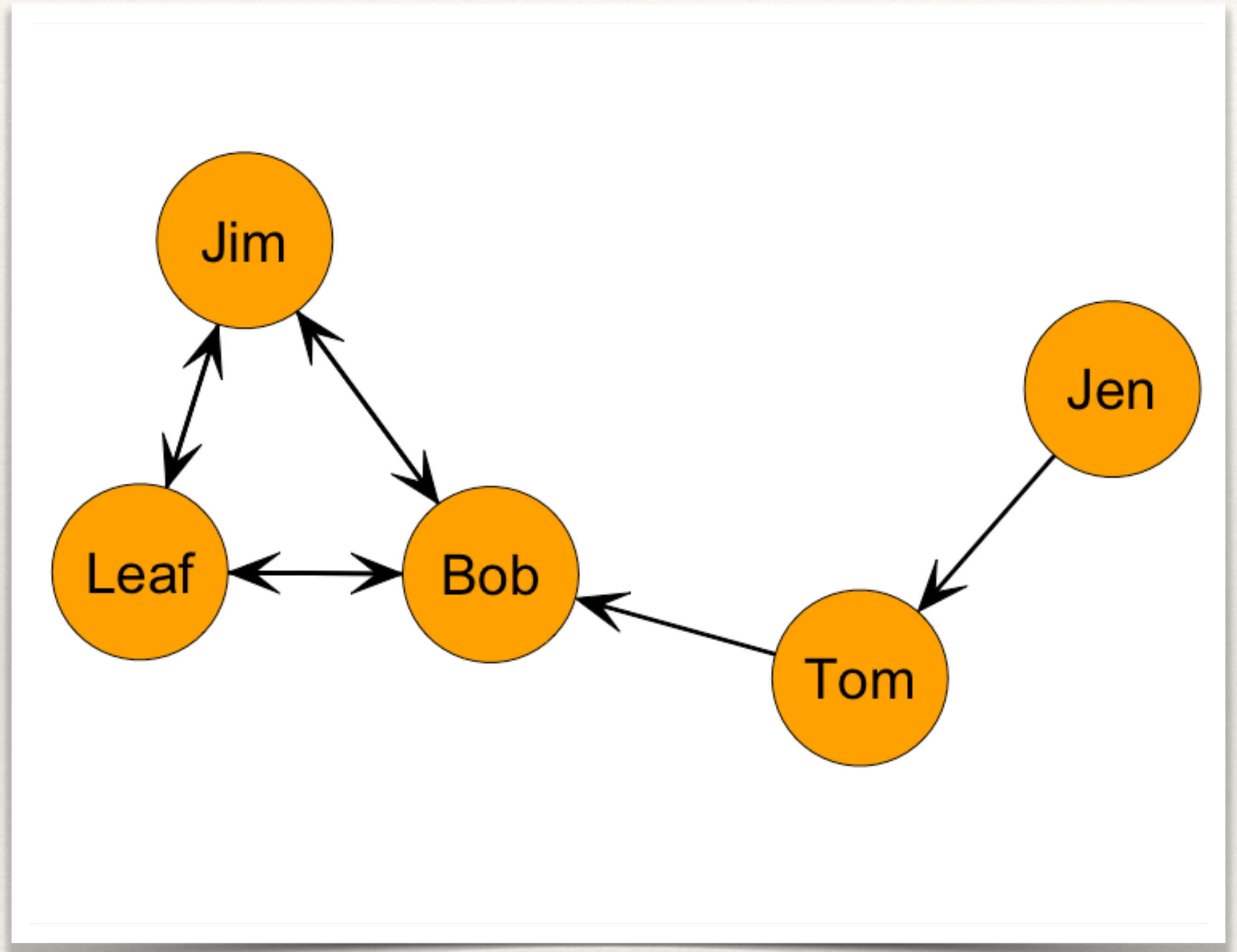


It looks like this.

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

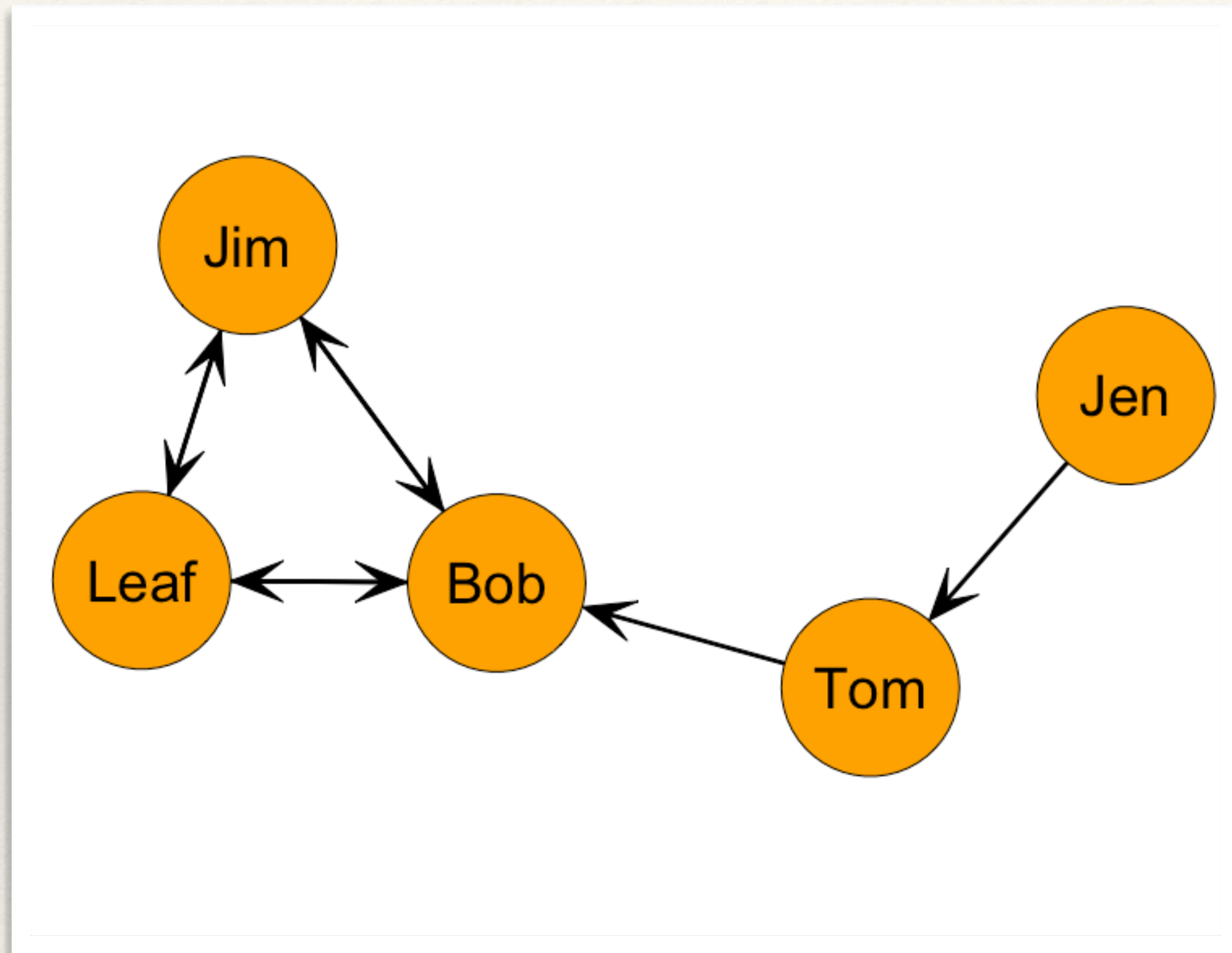
Example: Directed, Binary Network



	Jen	Tom	Bob	Leaf	Jim
Jen					
Tom					
Bob					
Leaf					
Jim					

What's different about a directed network?

Example: Directed, Binary Network

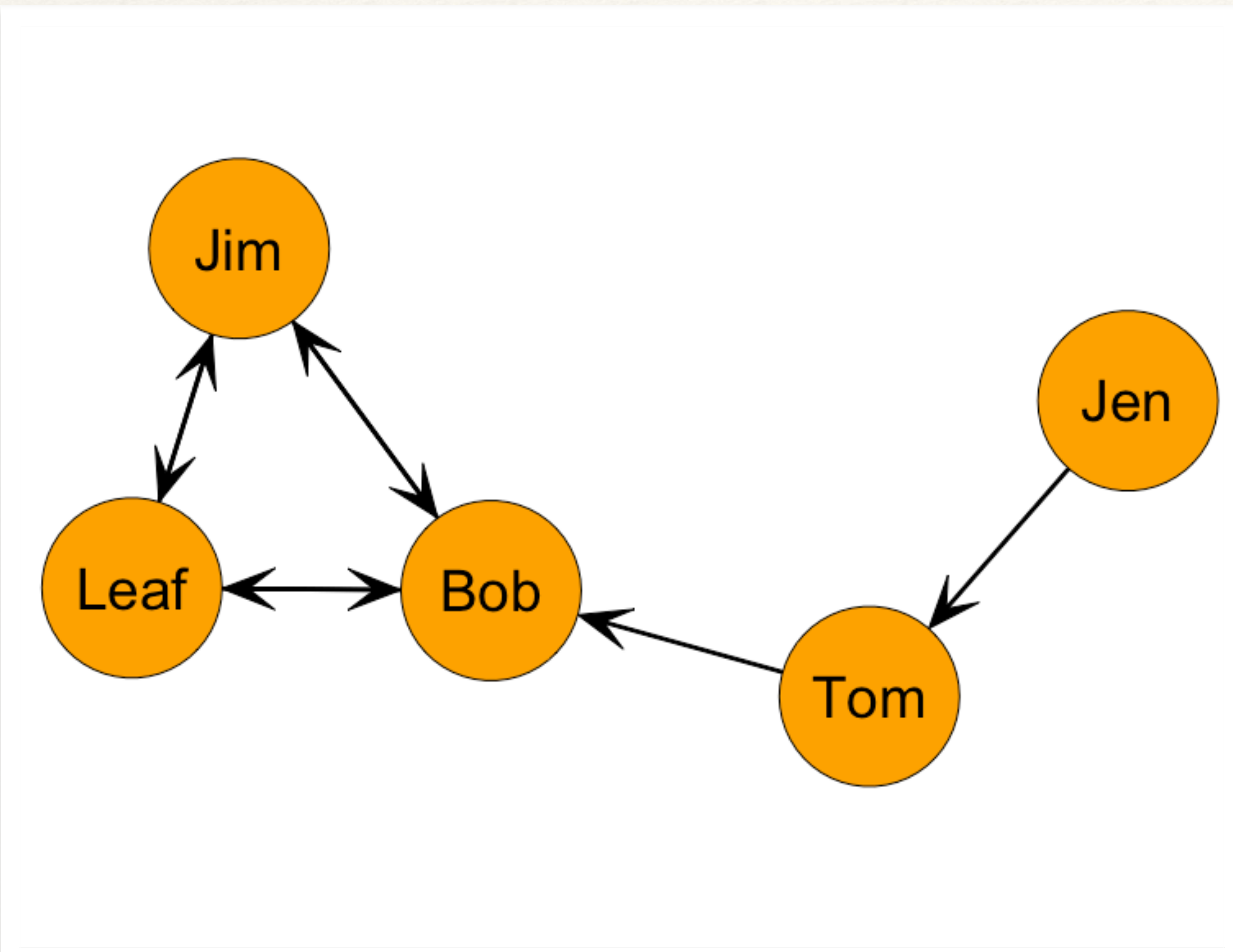


	Jen	Tom	Bob	Leaf	Jim
Jen		1			
Tom					
Bob					
Leaf					
Jim					

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

$$X_{12} = 1$$

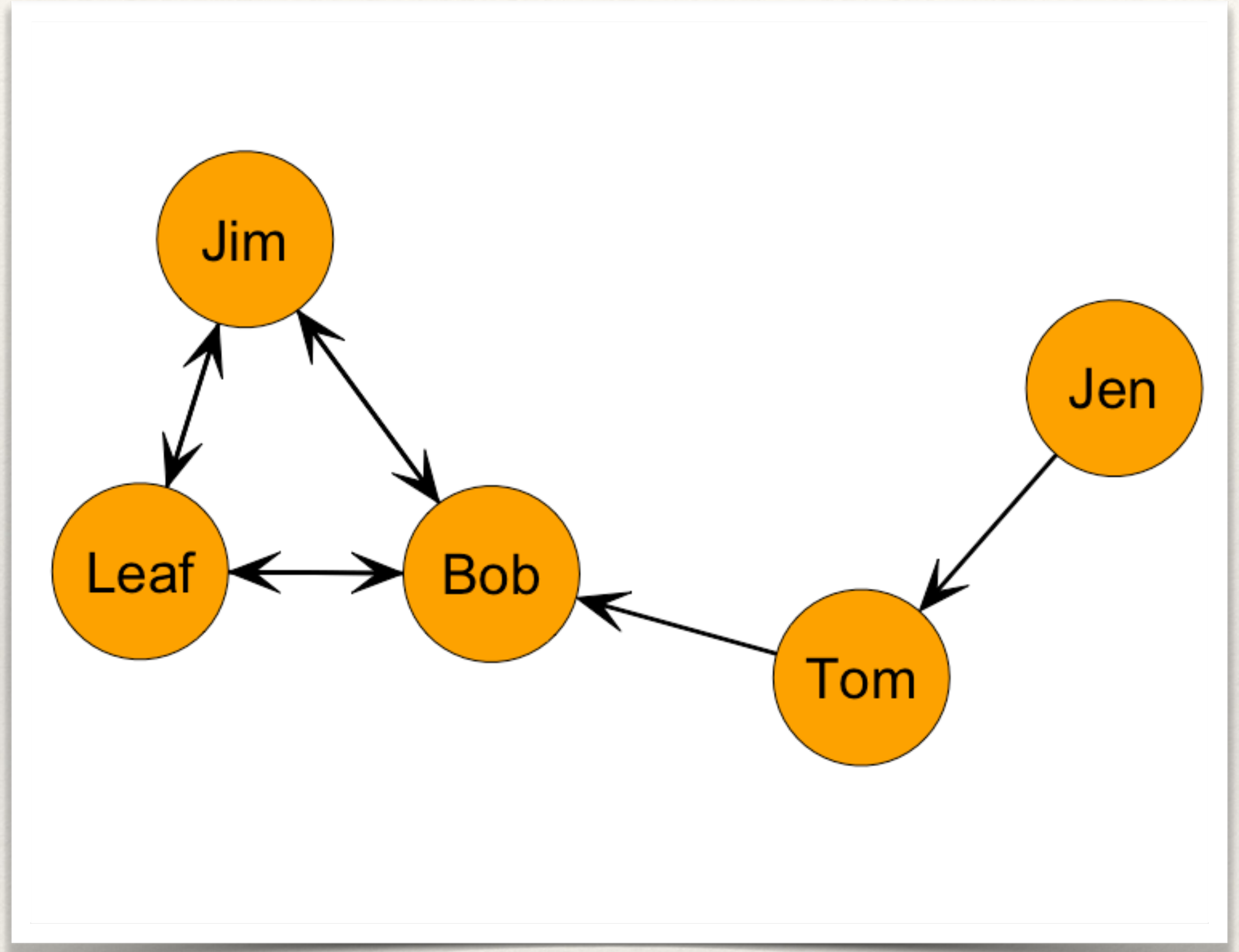
Example: Directed, Binary Network



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

But in the second row, *j* does not send:
$X_{21} = 0$

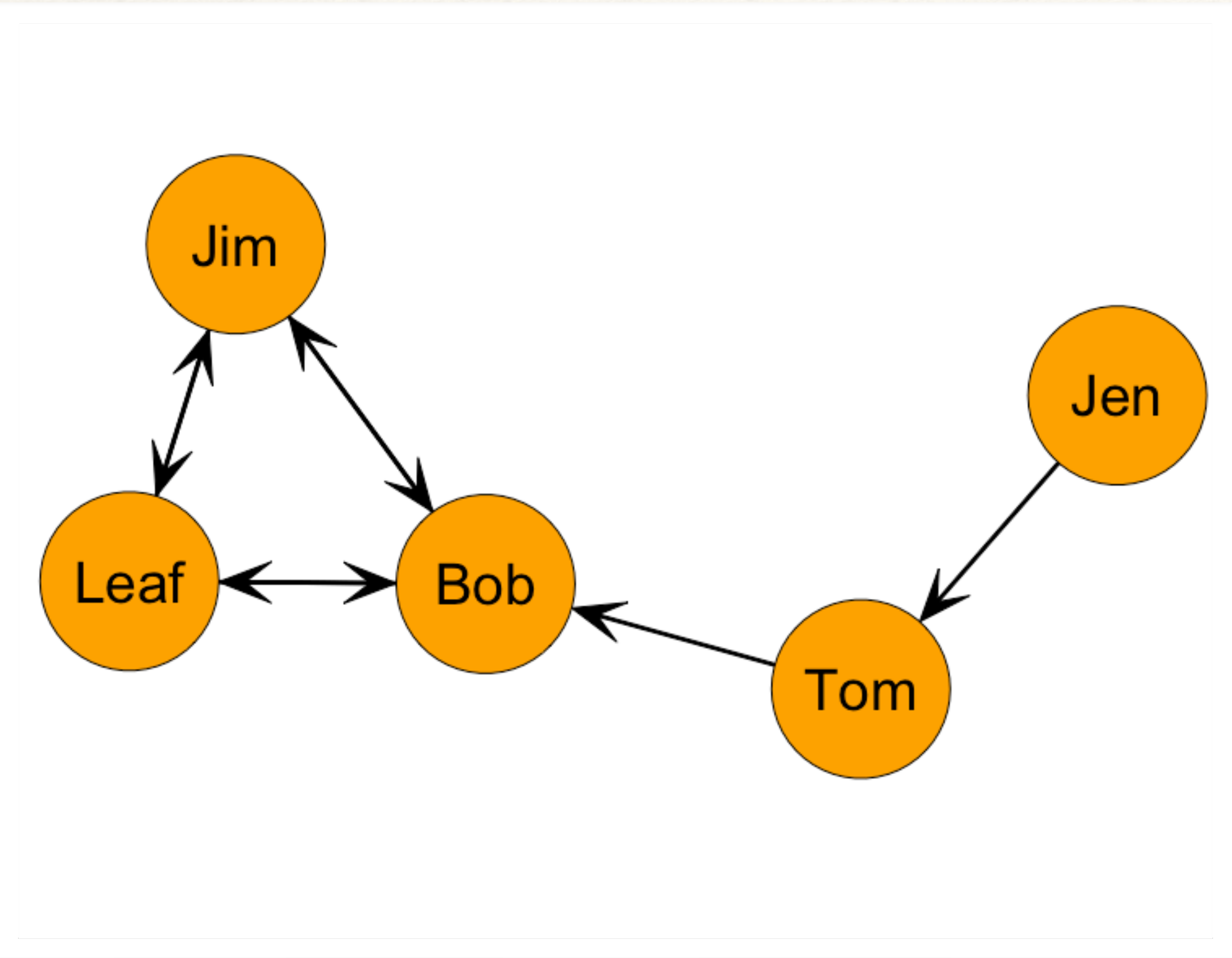
Example: Directed, Binary Network



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

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

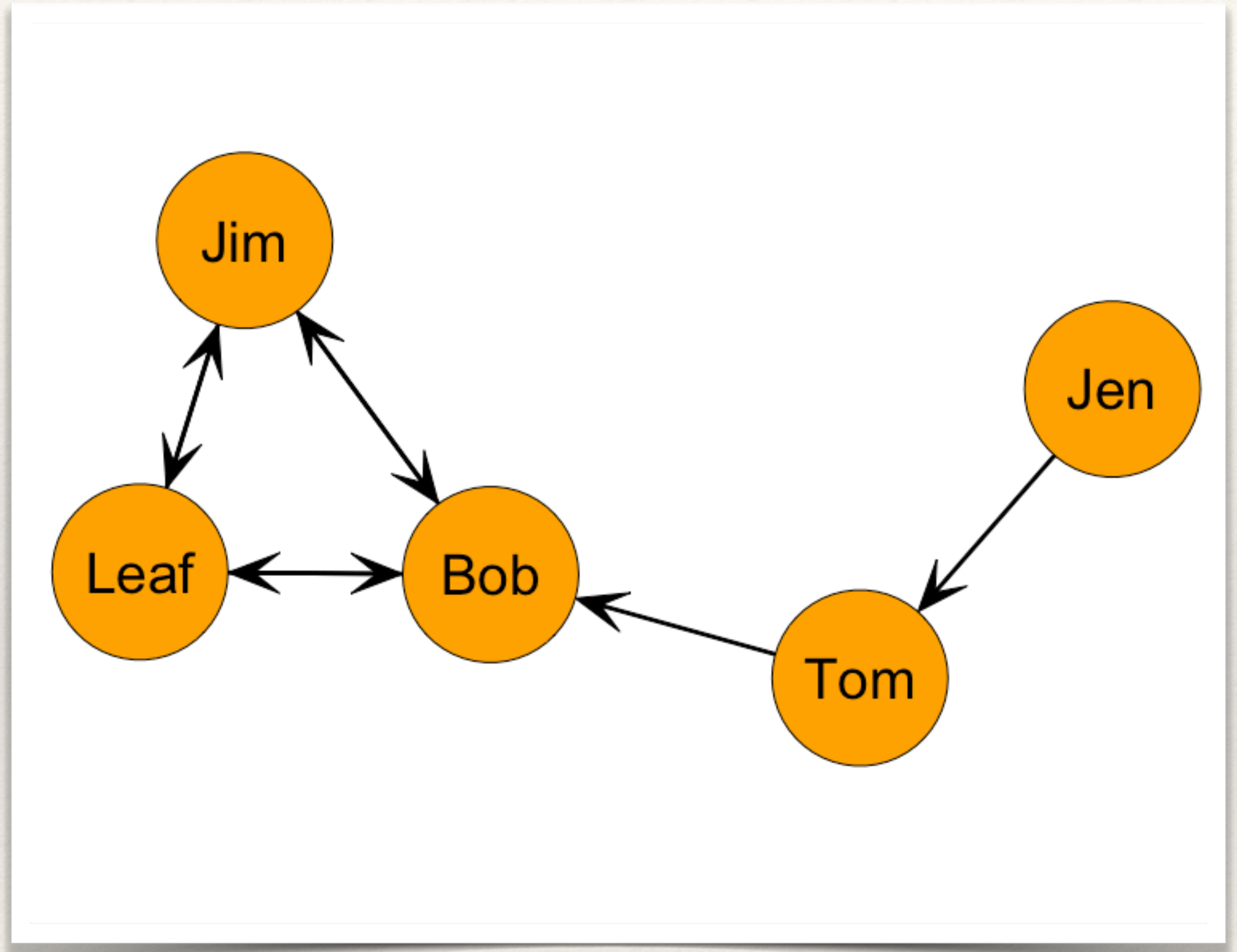
Example: Directed, Binary Network



	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**?

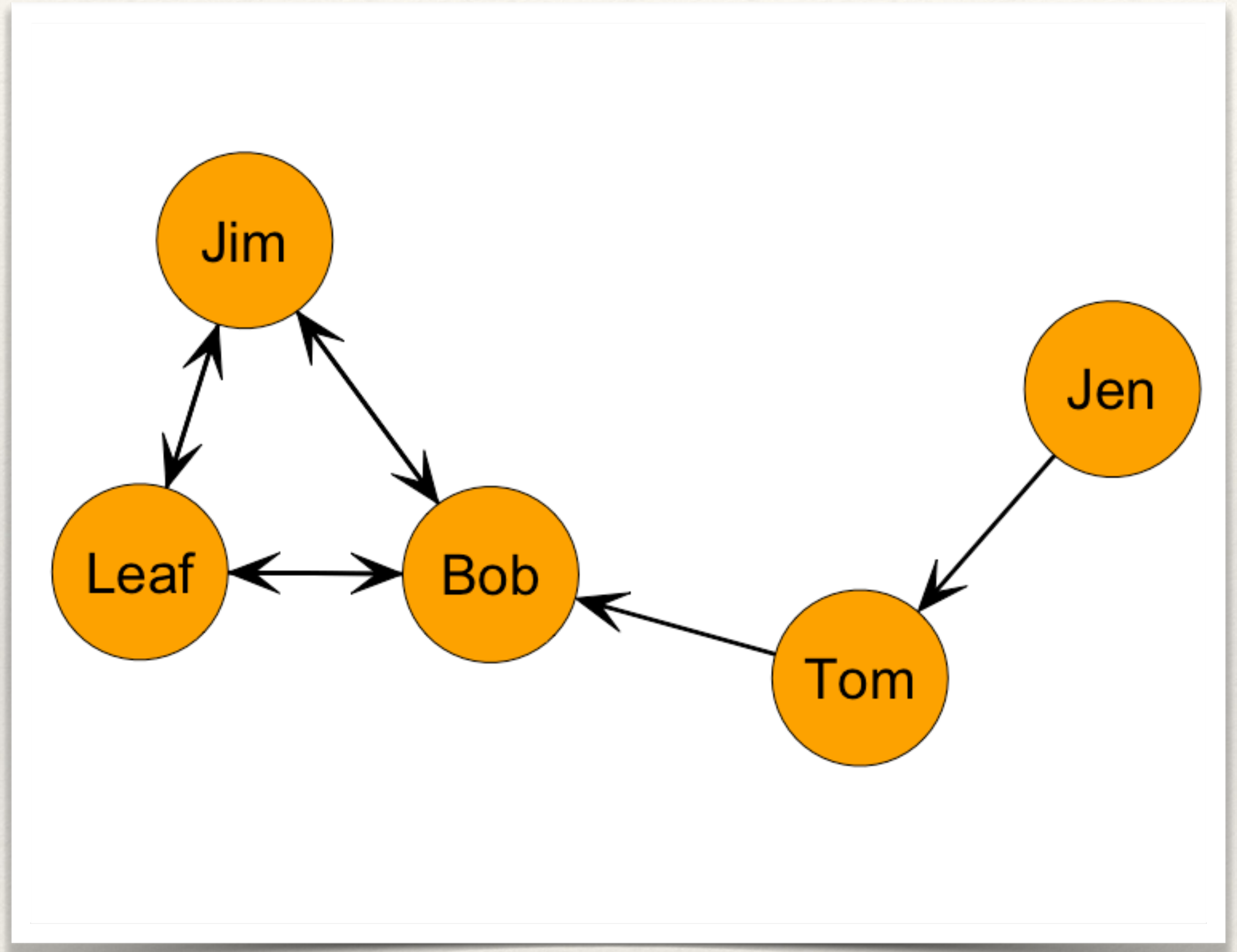
Example: Directed, Binary Network



	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)

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

Conceptualization

- <u>"Centrality" can mean different things</u>:
  - How many ties do you have? (degree)
  - How many people do you connect? (betweenness)
  - How far/near are you from people in the network? (closeness)

Conceptualization

- "Everyone agrees, it seems, that centrality is an important structural attribute of networks. All concede that it is related to a high degree to other important group properties and processes. But there consensus ends." (Freeman, 1978/1979: 217)
    - The type of measure we use depends on the substantive question of interest.
        - Various measures of centrality are correlated, but they <u>operationalize</u> different concepts.

Comparing Measures of Centrality

	Low Degree	Low Closeness	Low Betweenness
High Degree		Embedded in cluster that is far from the rest of the network	Ego's connections are redundant - communication bypasses him/her
High Closeness	Key player tied to important/active alters		Probably multiple paths in the network, ego is near many people, but so are others
High Betweenness	Ego's few ties are crucial for network flow	Very rare. Would mean that ego monopolizes the ties from a small number of people to many others	

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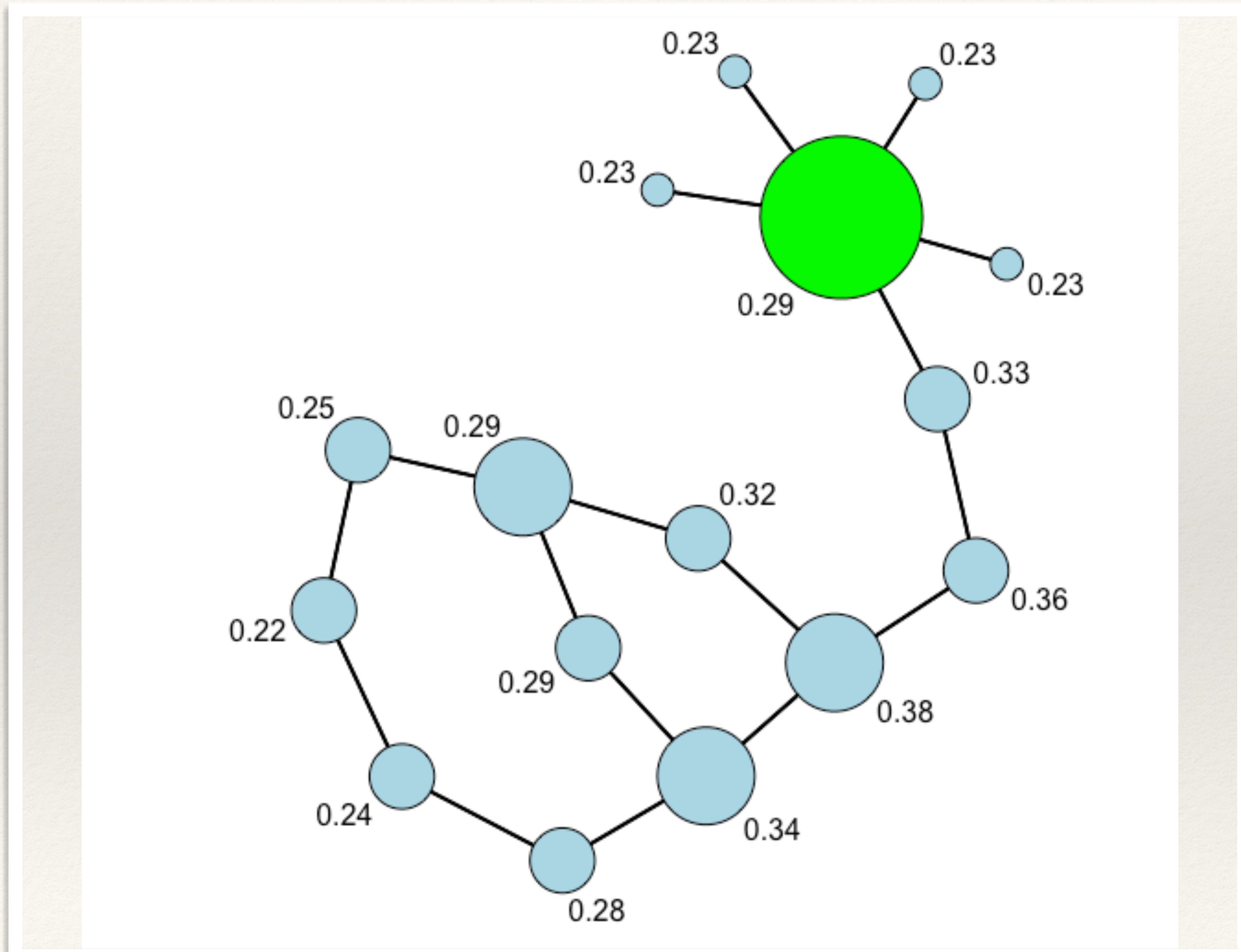
High Degree, Low Closeness



Nodes sized by degree

Nodes labeled by closeness centrality

Comparing Measures of Centrality

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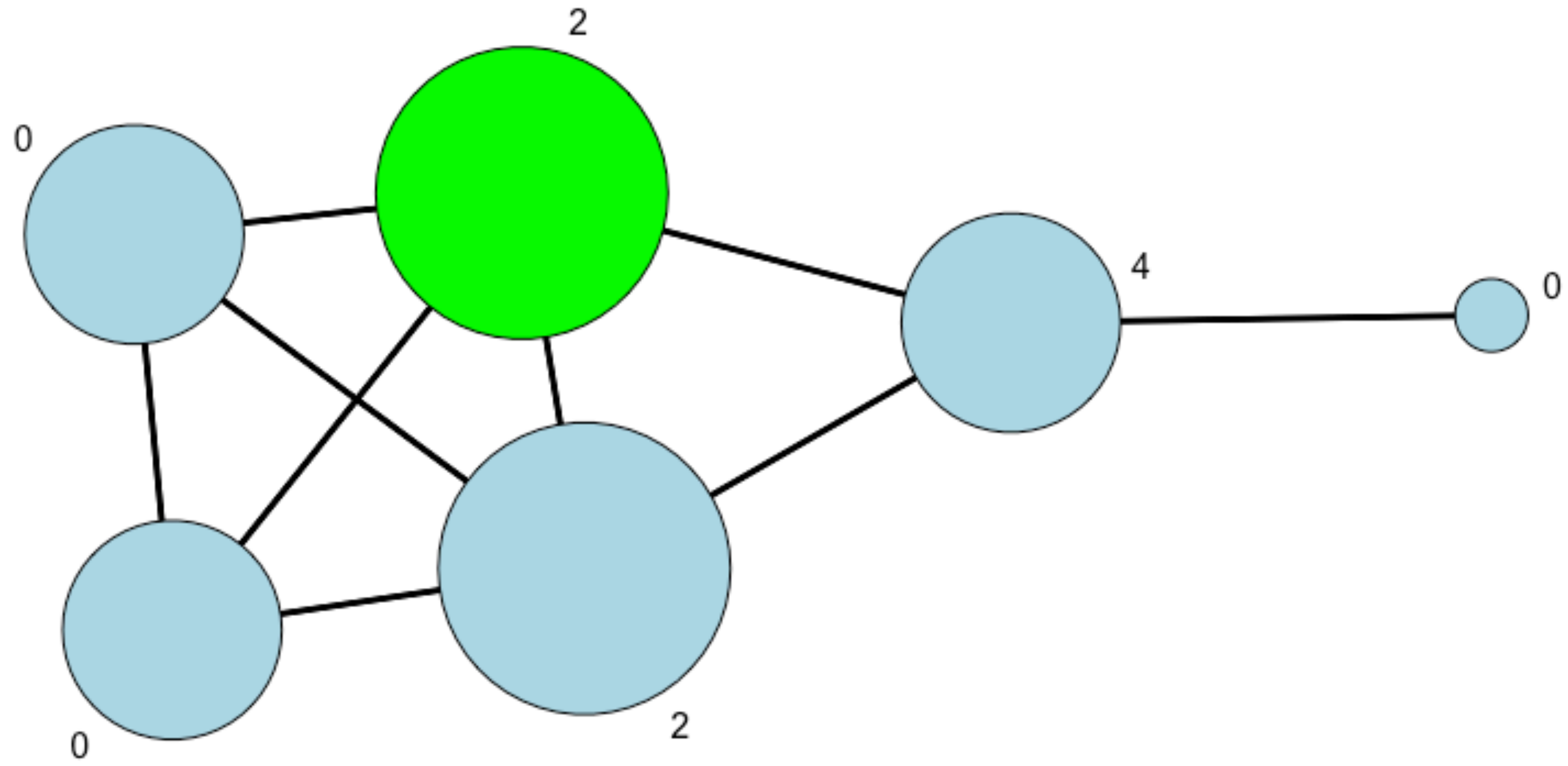

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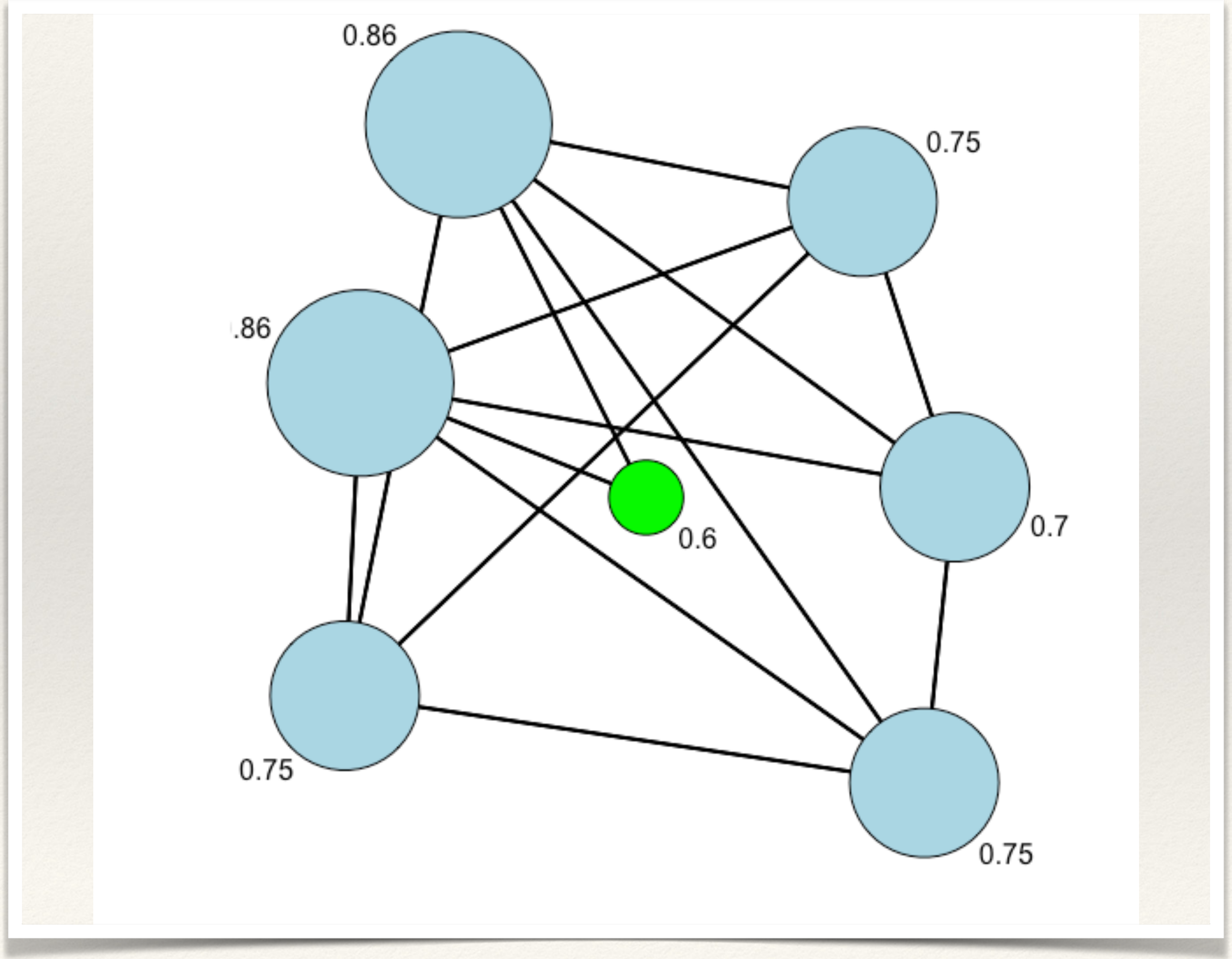
High Closeness, Low Degree



Nodes sized by degree centrality

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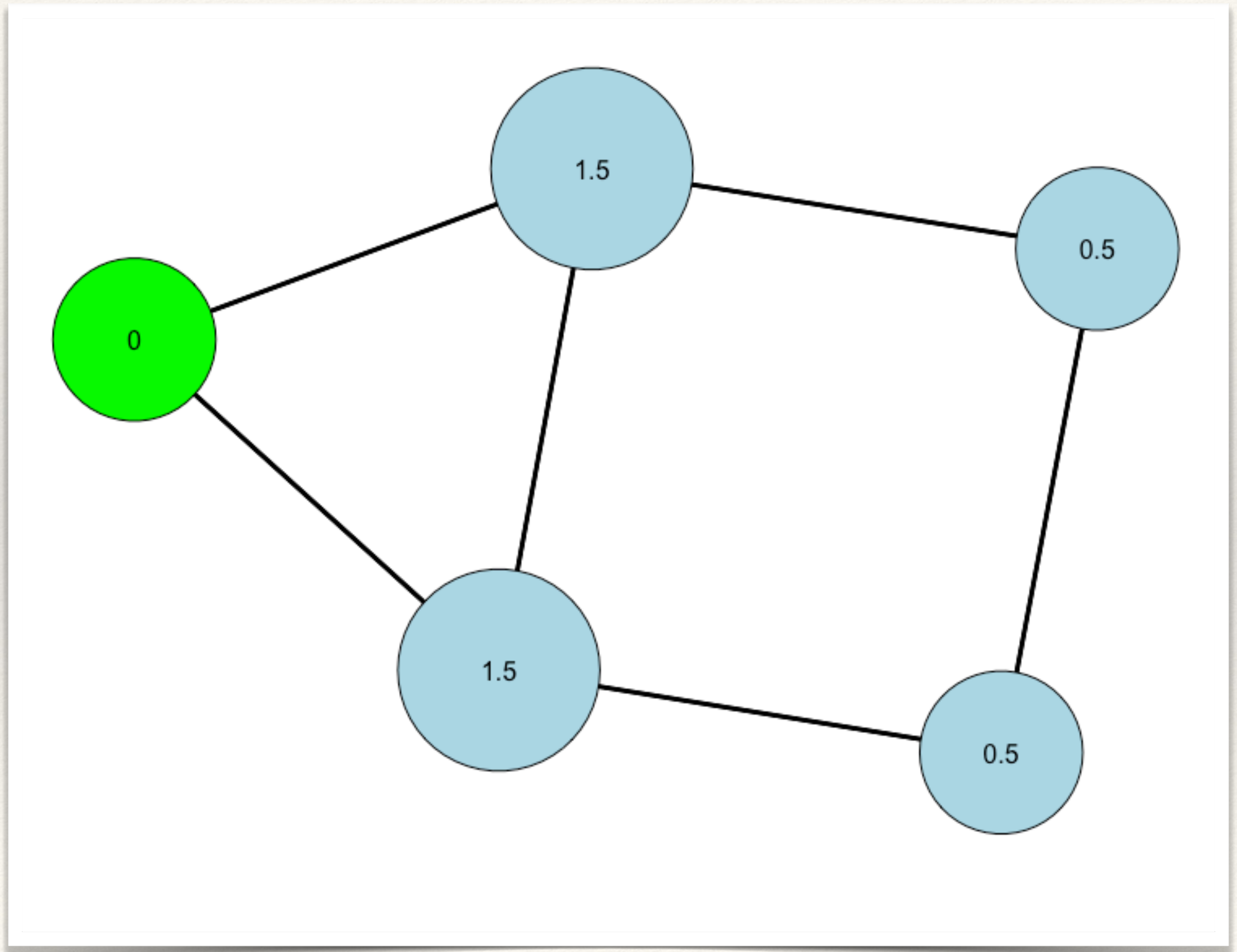
High Closeness, Low Betweenness



Nodes sized by closeness centrality

Nodes labeled by betweenness centrality

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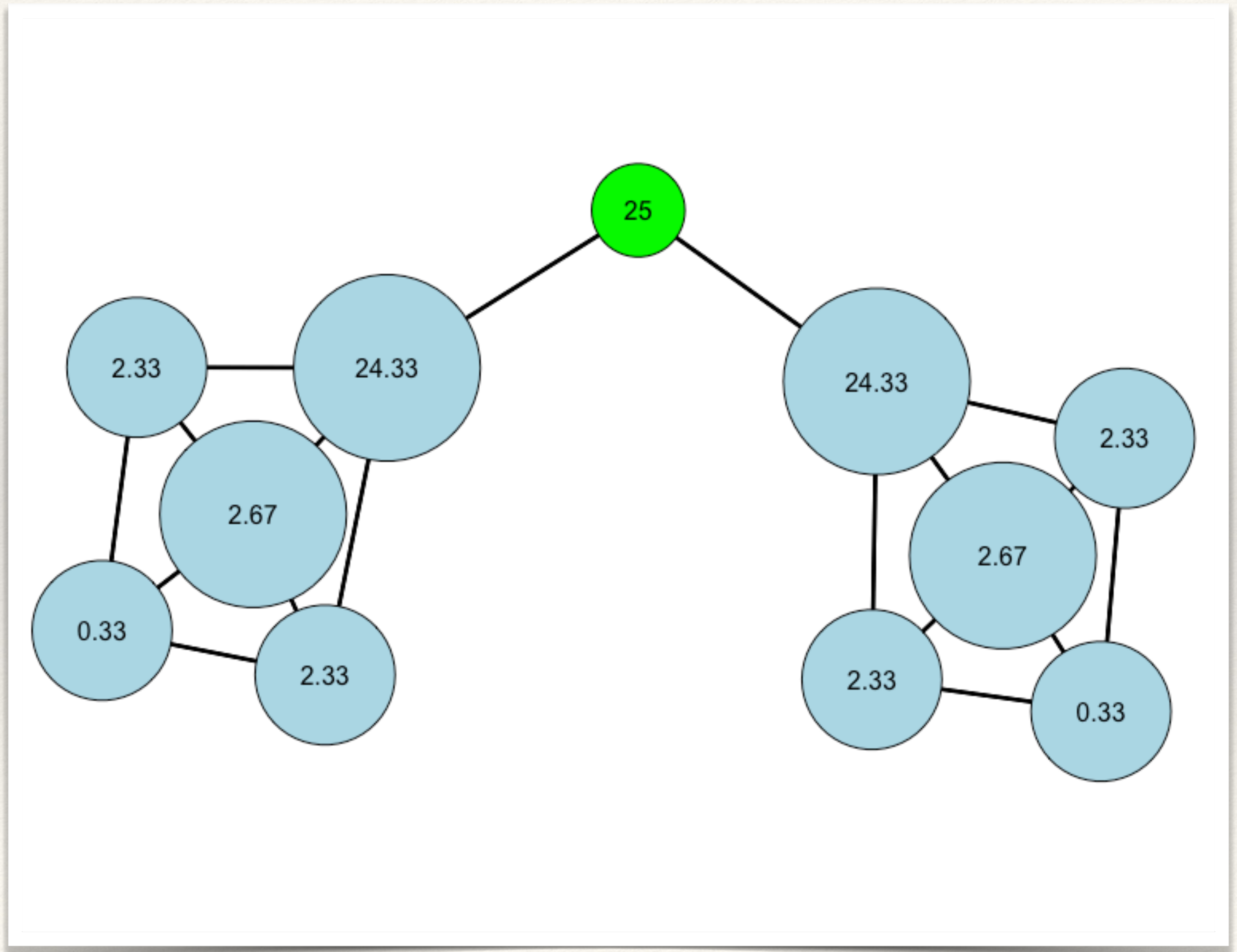
High Betweenness, Low Degree



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Comparing Measures of Centrality

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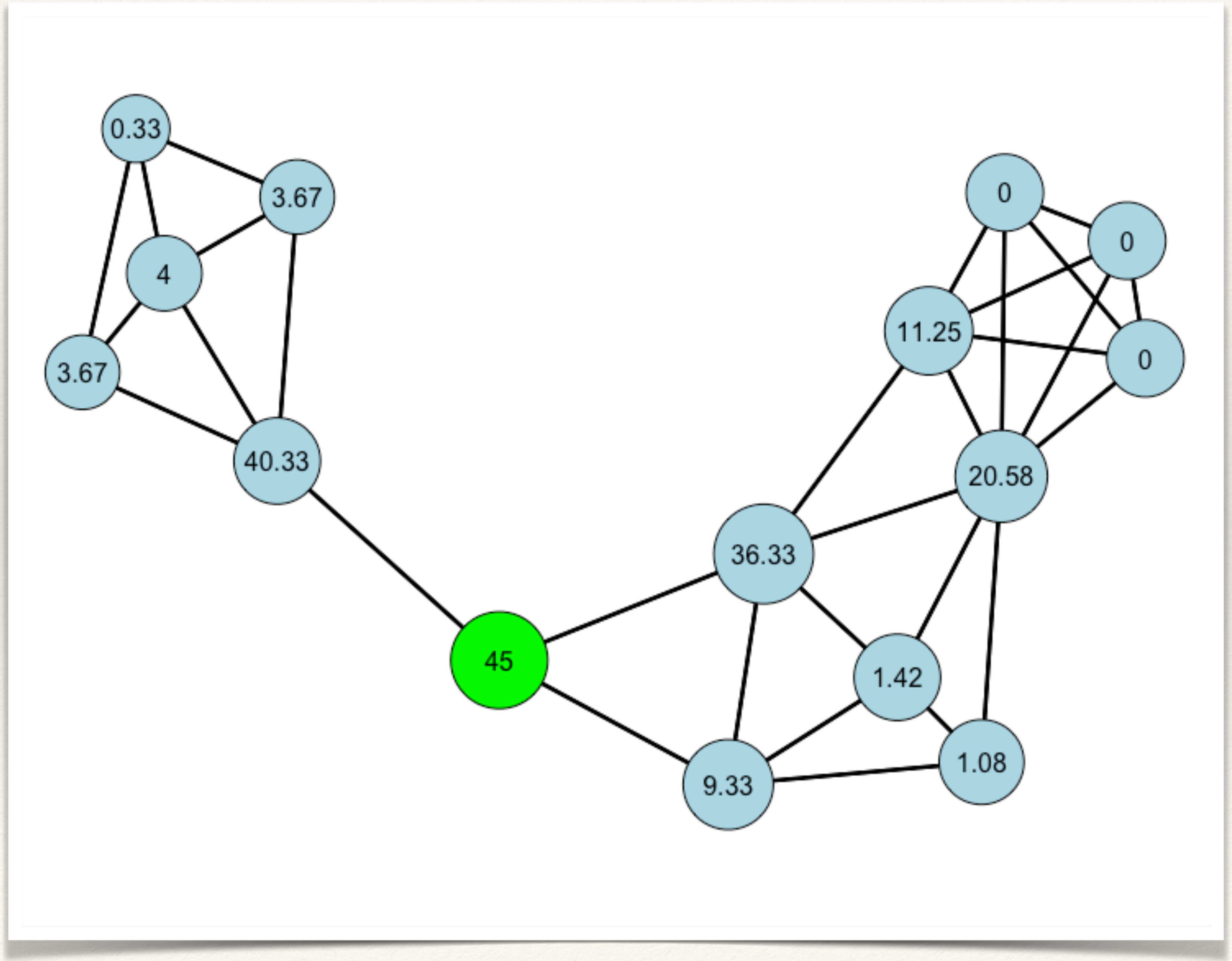
High Betweenness, Low Closeness



Nodes sized by closeness centrality

Nodes labeled by betweenness centrality

Network Analysis

- What sort of analysis you do depends on the question:
  - Do attitudes spread through simple or complex processes? (diffusion)
  - Do adolescents sort into subgroups? (modularity)
  - Are particular networks more vulnerable than others? (degree assortativity)
  - And so on…

Summary

- Network analysis can be simple or complex, descriptive or inferential.
- But, remember the crucial steps:
  - **Conceptualizing** theoretical concepts that are inherently relational.
  - **Operationalizing** theoretical constructs by drawing on the formal properties of graphs.

Questions?

Examples from my research

Example

- Young, J. T. N. (2013). "Role Magnets"? An Empirical Investigation of Popularity Trajectories for Life-Course Persistent Individuals During Adolescence. *Journal of youth and adolescence*. http://link.springer.com/article/10.1007%2Fs10964-013-9946-0.

    - Goal: Examine the developmental trajectory of popularity during adolescence for violent individuals.
    - Concept: Popularity
    - Operationalization: Indegree Centrality
    - Expectation: violent individuals should experience an increase in popularity during adolescence, then a decline.

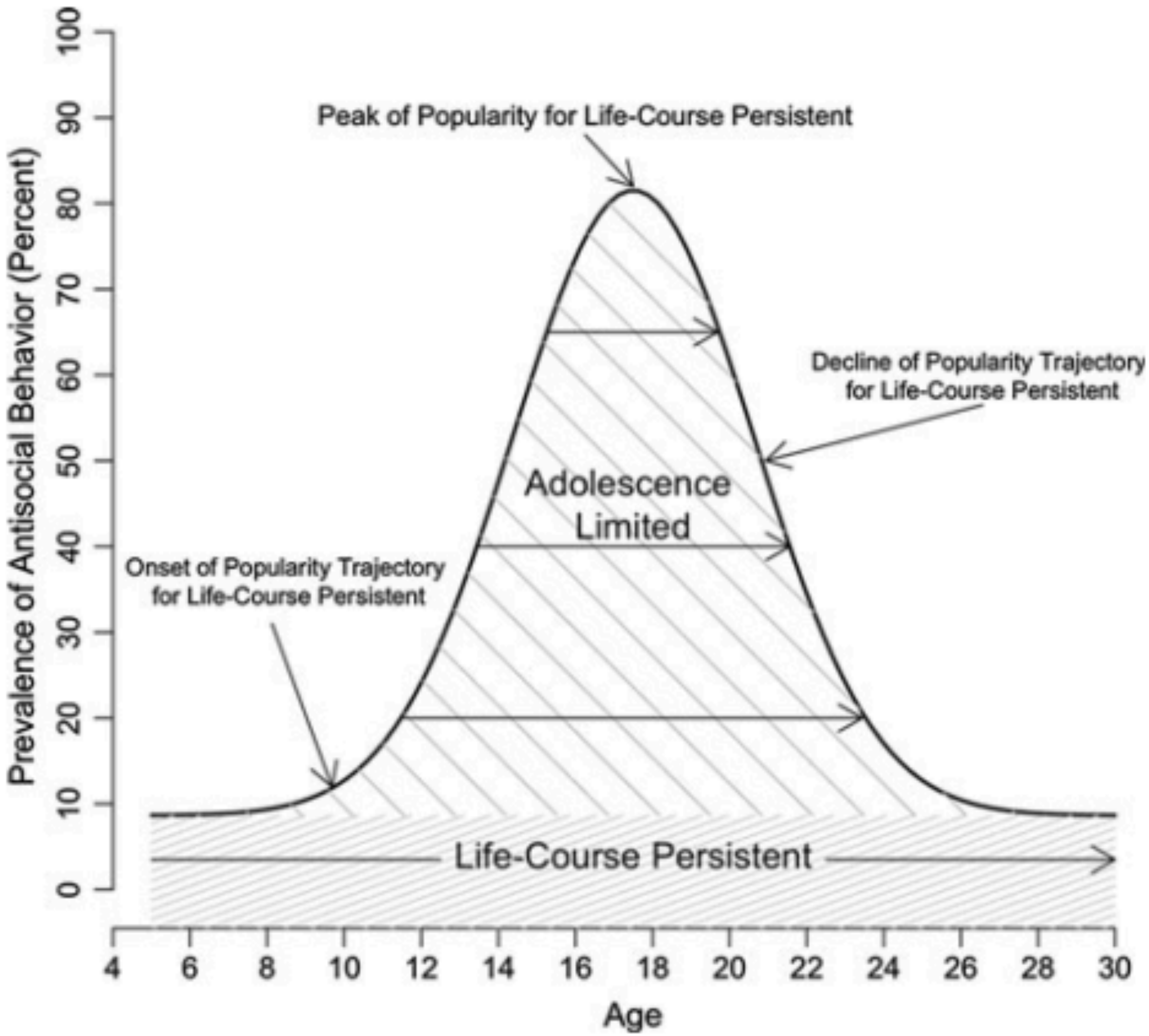


Fig. 1 Hypothetical illustration of the prevalence of antisocial behavior. *Arrow length* represents duration of participation in antisocial behavior

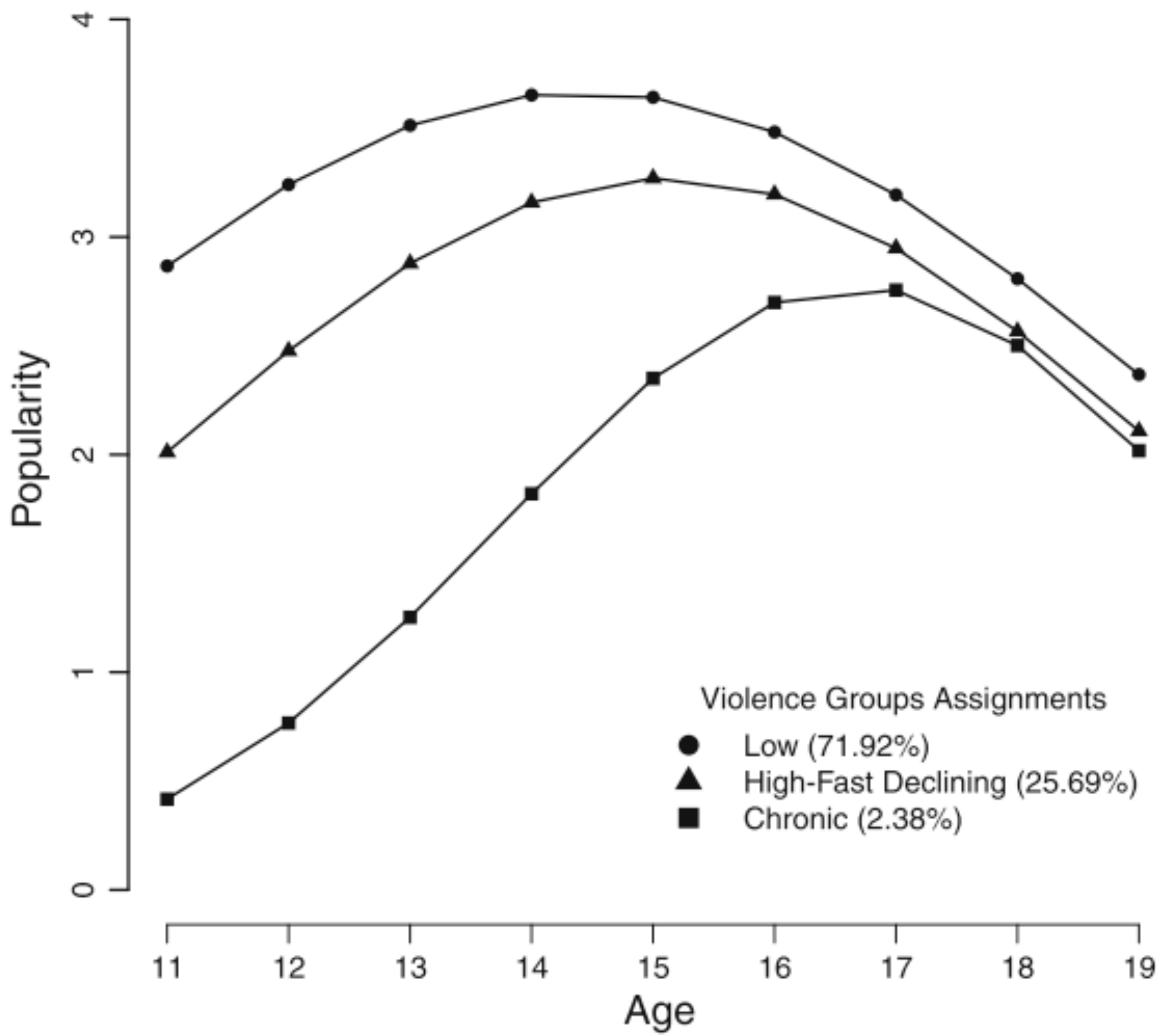
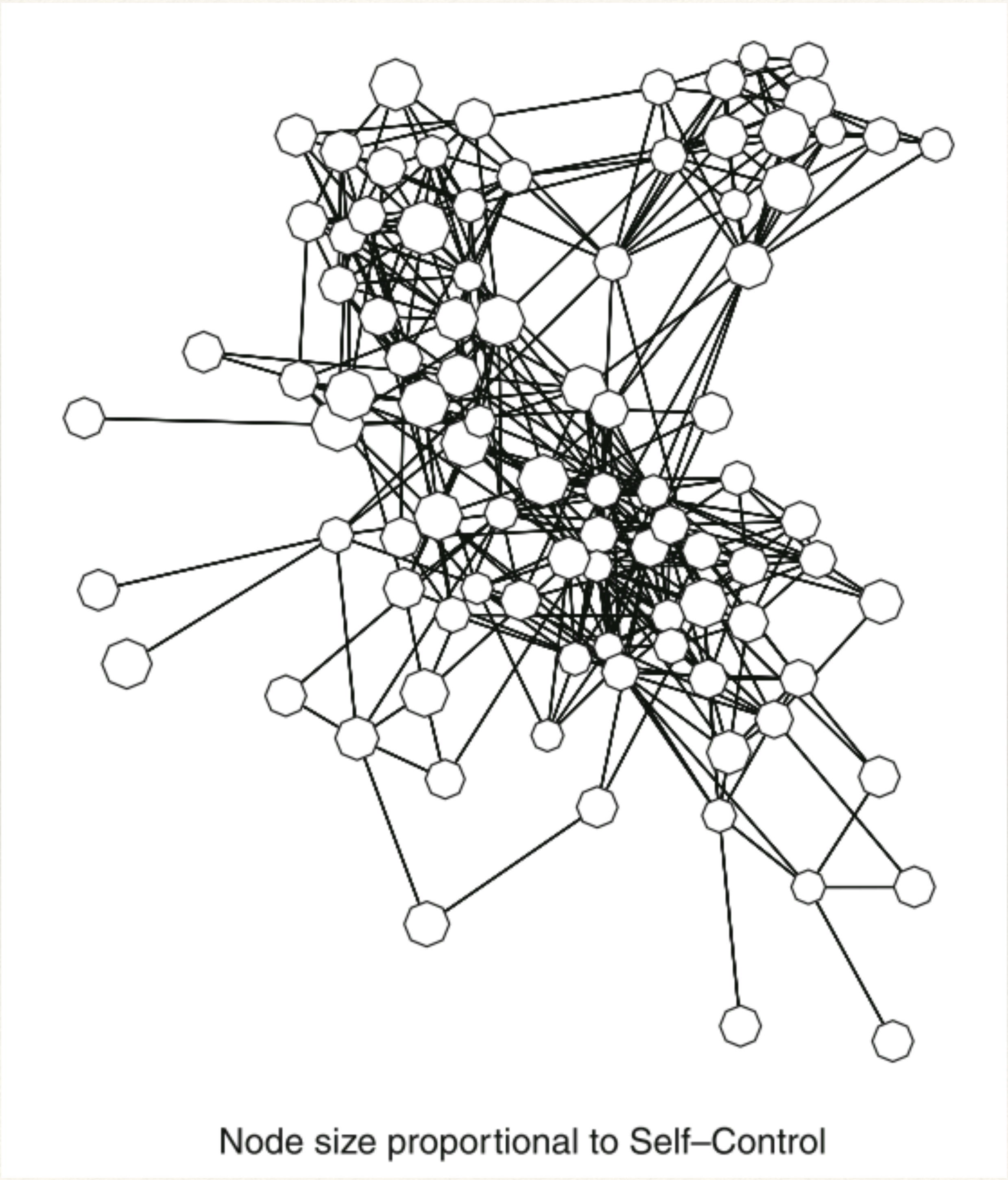


Fig. 3 Predicted growth trajectories for popularity by age and violence trajectory group

Example

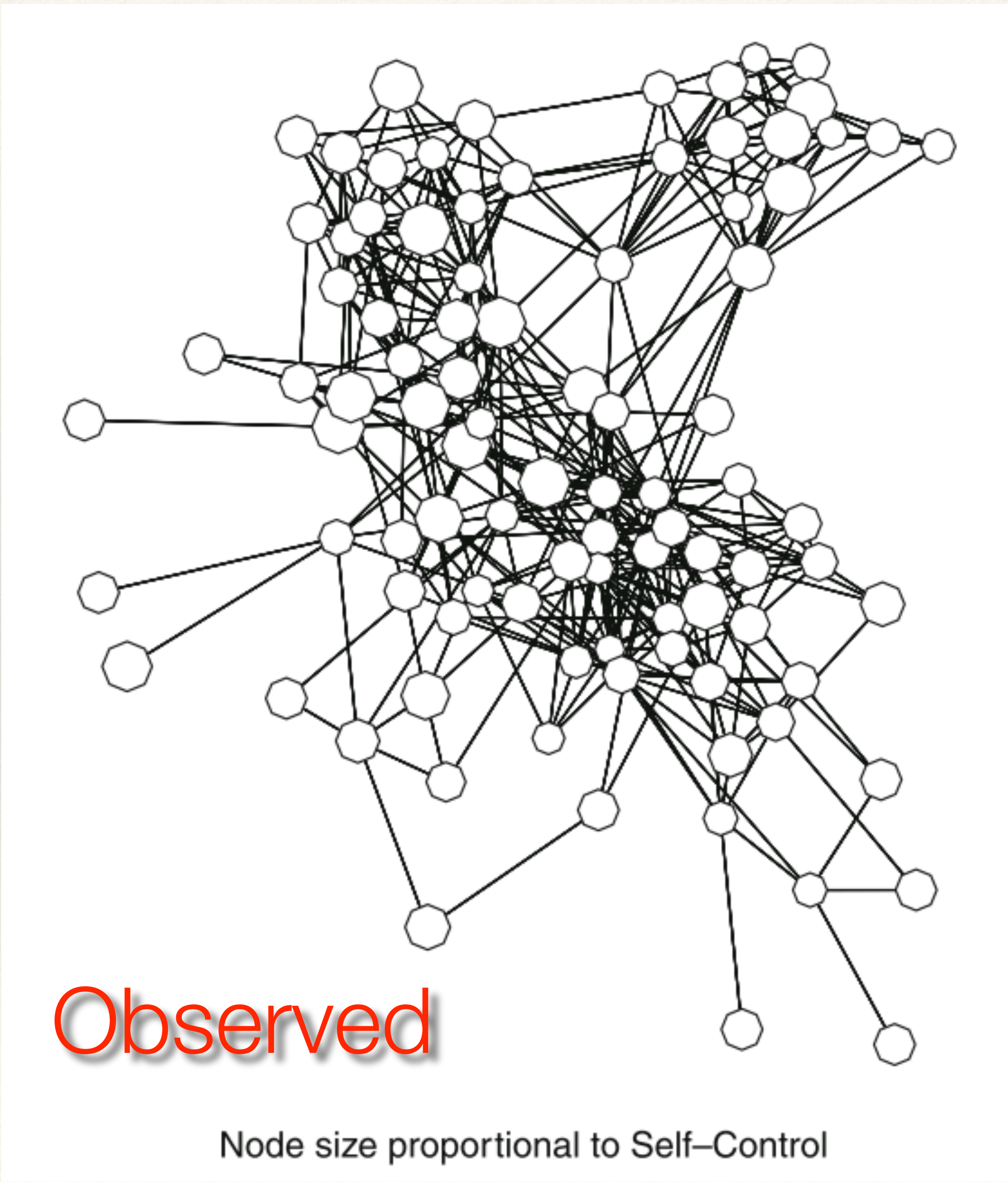
- Young, J. T. N. (2011). How Do They “End Up Together”? A Social Network Analysis of Self-Control, Homophily, and Adolescent Relationships. Journal of Quantitative Criminology, 27(3), 251–273. https://doi.org/10.1007/s10940-010-9105-7.
  - Question: What generates the correlation between an individuals level of self-control and his/her peers?
    - Concept: Homophily
      - A node-based mechanism: Selective mixing
      - A structural mechanism: Transitivity

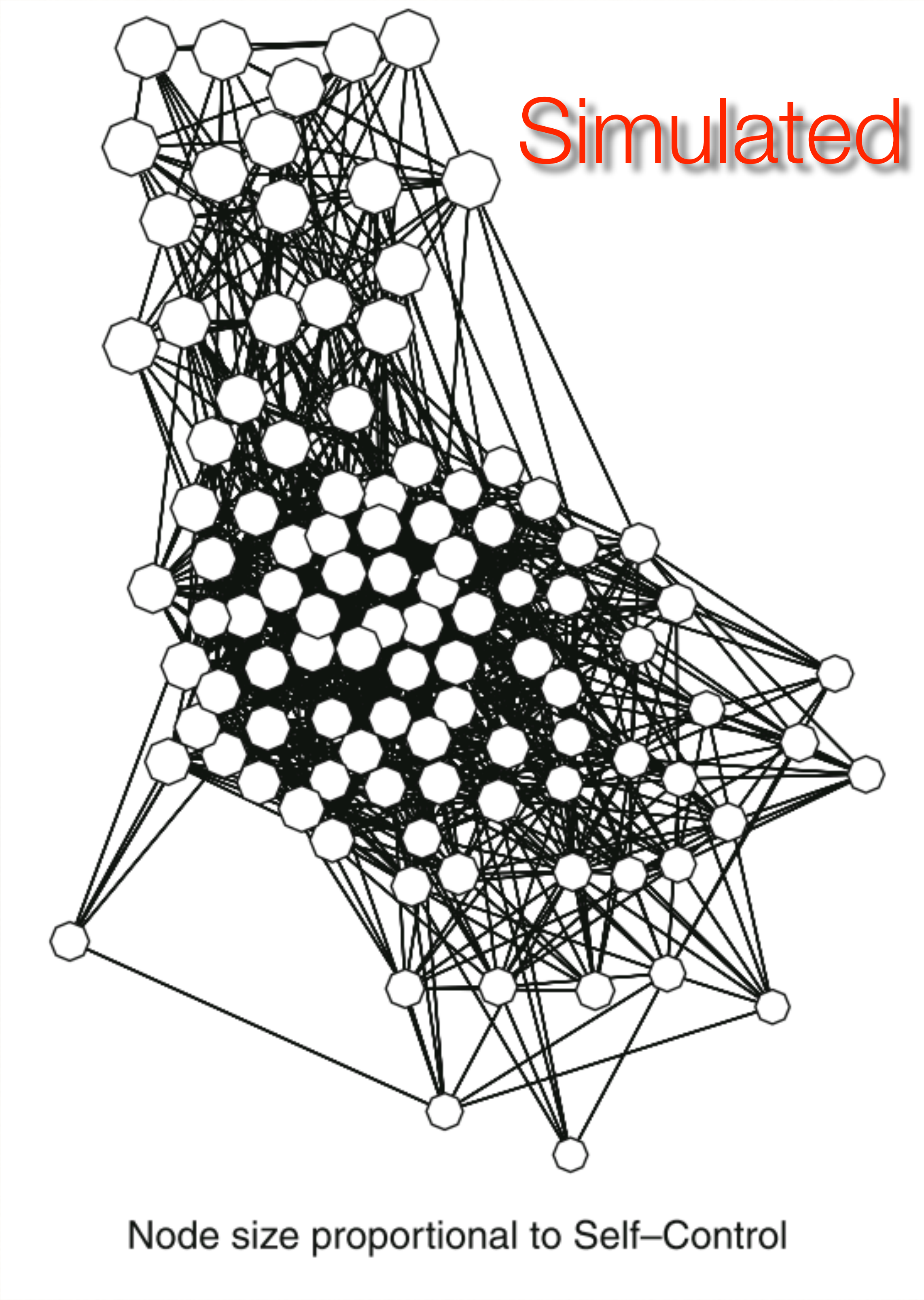
Exponential Random Graph models to the rescue!



- Specify a model of how ties form.
- Then, compare the observed data to a model where ties form at random.

- *Take away?*


Observed
Node size proportional to Self–Control


Simulated
Node size proportional to Self–Control

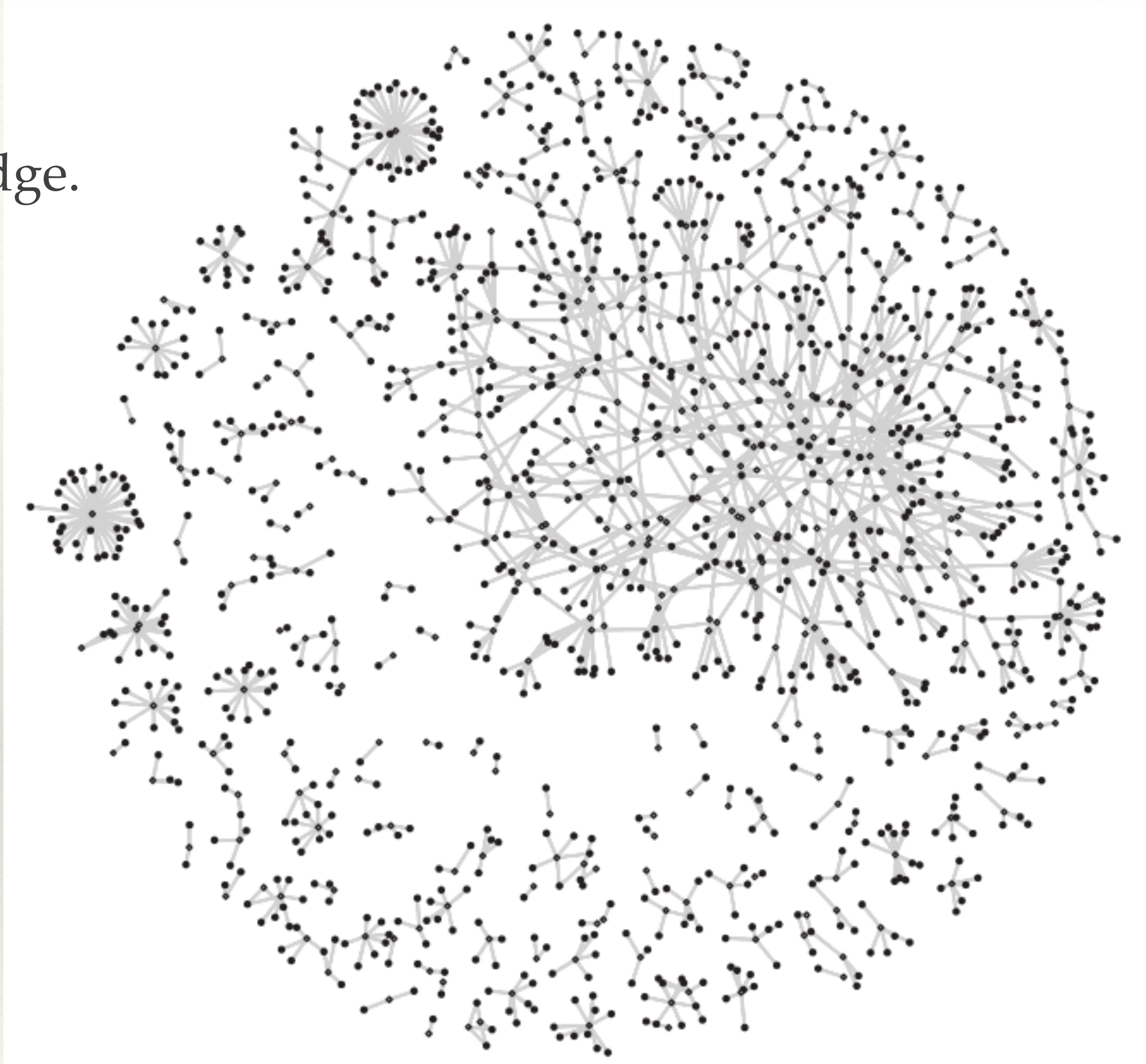
Example

- Fahmy, C., & Young, J. T. N. (2015). Invisible Colleagues: The Informal Organization of Knowledge Production in Criminology and Criminal Justice. Journal of Criminal Justice Education, (June), 1–23. https://doi.org/10.1080/10511253.2015.1051999
    - Question: how are acknowledgements organized?
        - Concept: informal knowledge production.
        - Measurement: acknowledgements in journals
            - a two-mode network

Example

- Articles in white
- Acknowledgees in black
- *Anything about the structure of this stick out to you? (Other than being blurry)*

- 83% of nodes receive only 1 edge.
- 3 people had 10!



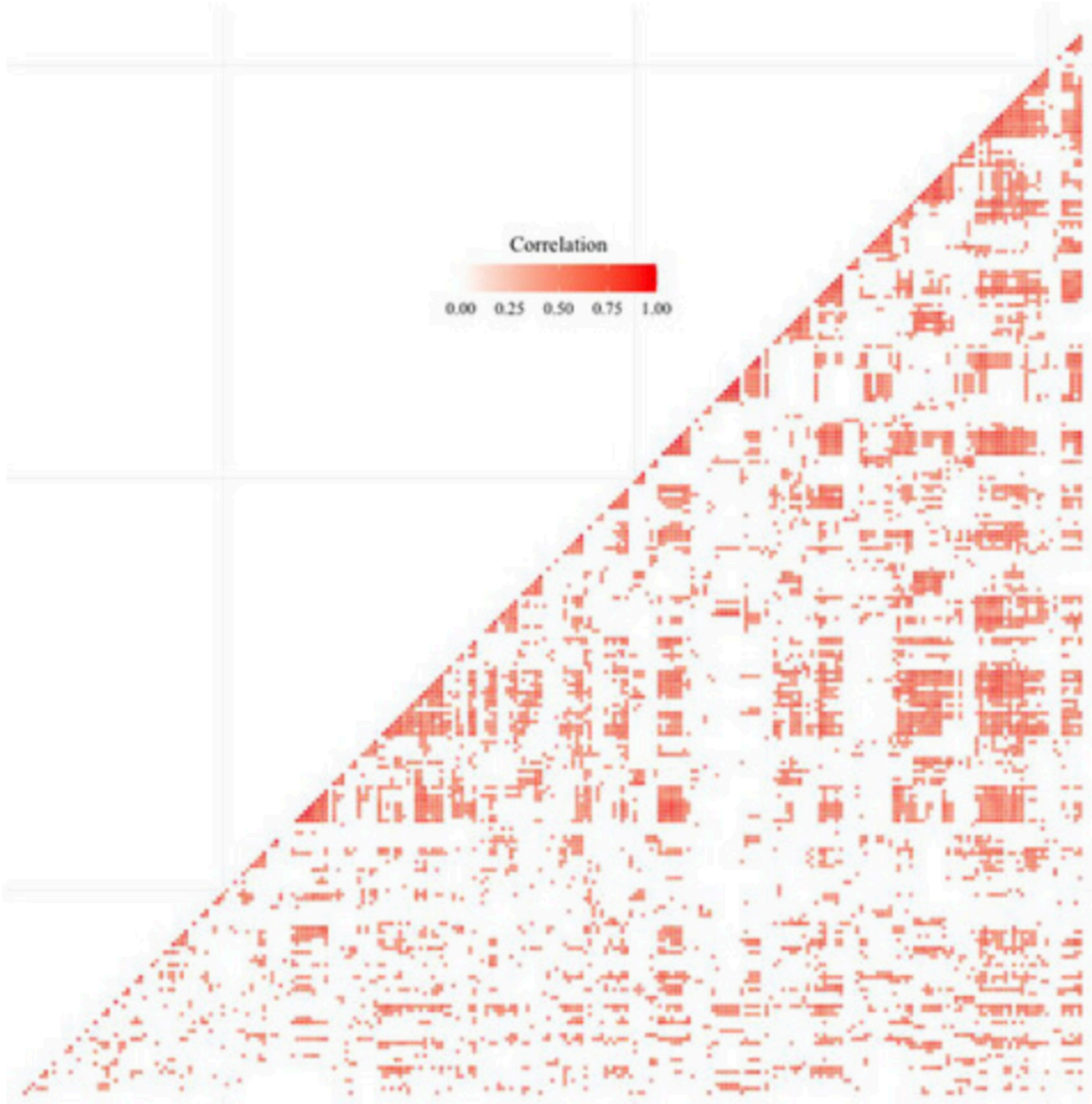
- What does it mean?

Example

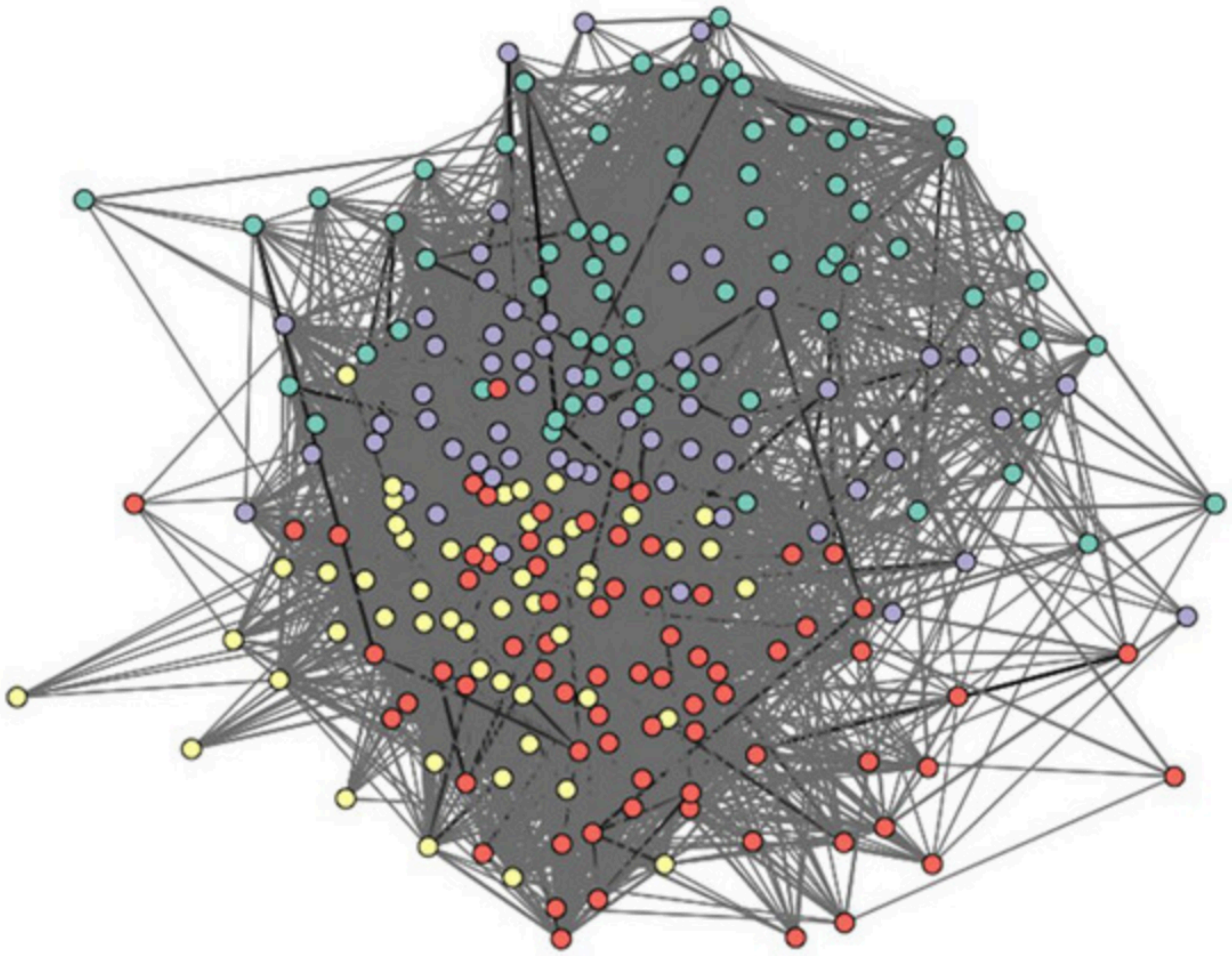
- Young, J. T. N., Meyers, T. J., & Morse, S. J. (2023). What is "prison culture"? Developing a theoretical and methodological foundation for understanding cultural schema in prison. *Criminology*, *61*(3), 421-448. https://doi.org/10.1111/1745-9125.12335
  - Question: what does it mean to say that a prison has a 'culture'?
    - Concept: **culture** is a "shared understanding"
    - Measurement: modularity of an agreement matrix for two cultural domains (prison code and race)
      - Weighted sociomatrix

Example

Correlations among Respondents for Prison & Racial Code Items

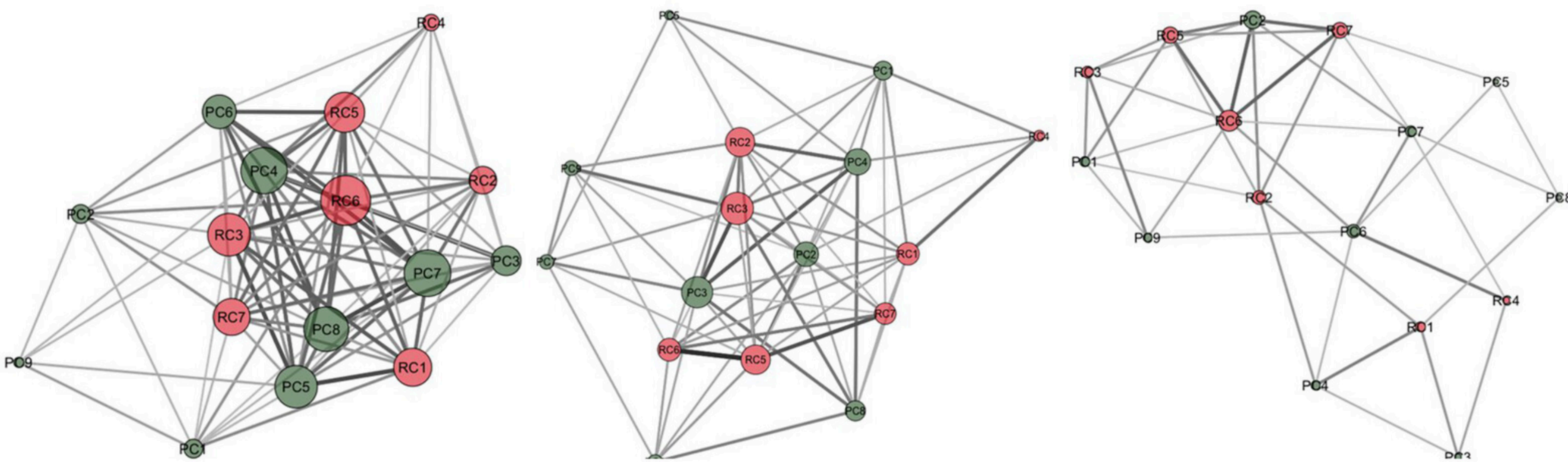


Weighted Network of Correlations among Respondents for Prison & Racial Code Items

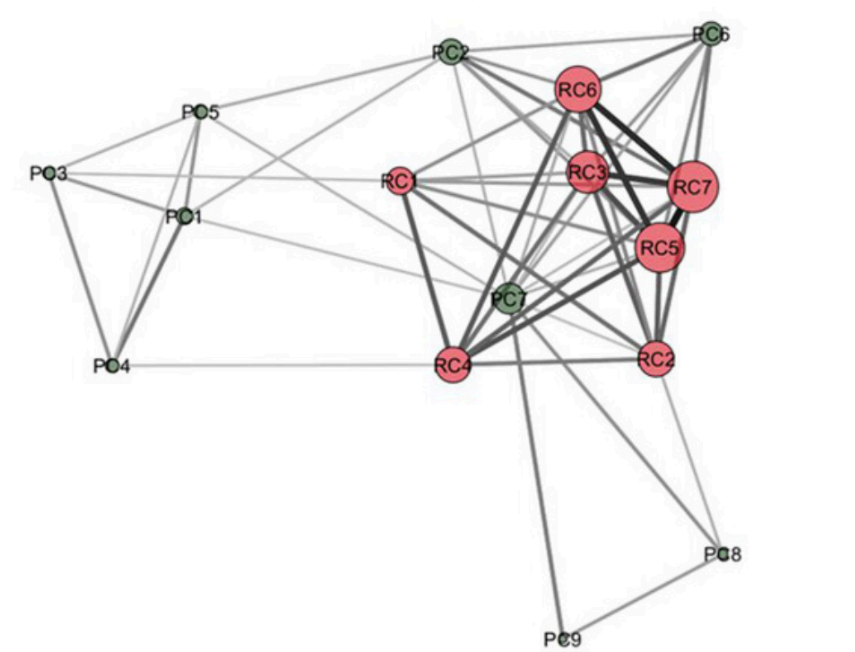


Example

First Schematic Class Second Schematic Class Third Schematic Class



Fourth Schematic Class



Items	Average Item Correlation			
	S1	S2	S3	S4
Prison Code ("it is important to...")				
Mind your own business and pretend like you don't see or hear what is going on around you (PC1)	.27	.25	.18	.16
Not help other inmates if they are in trouble or hurt (PC2)	.25	.27	.26	.25
Show strength and toughness at all times (PC3)	.32	.34	.14	.12
Never show fear (PC4)	.45	.31	.16	.13
Not leak information to a correctional officer about an inmate (PC5)	.42	.17	.26	.16
Not help prison staff when they need it (PC6)	.37	.22	.17	.23
Be loyal to inmates and not loyal to prison staff (PC7)	.45	.19	.17	.26
Defend your reputation at all costs (PC8)	.44	.26	.17	.19
Keep to yourself as much as possible (PC9)	.21	.21	.17	.12
Racial Code ("it is important to...")				
Be loyal to your race (RC1)	.41	.28	.17	.26
Segregate by race for protection (RC2)	.32	.31	.22	.28
Defend your racial group at all costs (RC3)	.41	.35	.22	.29
Obey the rules of your racial group (RC4)	.25	.19	.17	.33
Do what the people in your racial group tell you, even if it means beating, injuring, or harming someone (RC5)	.41	.35	.23	.34
Do what your racial group tell you, even if it means risking getting a ticket (RC6)	.47	.29	.23	.34
Make sacrifices for your racial group, even if it mean harming yourself or others (RC7)	.38	.29	.23	.34

Where to go from here…

Resources

- The internet
- Check out professional associations
  - INSNA (insna.org)
- Journals
  - *Social Networks*
  - *Network Science*

Computation

- R (cran.r-project.org)
  - https://jacobtnyoung.github.io/RWorkshop/
- UCINET
  - https://sites.google.com/site/ucinetsoftware/home

WARNING! Shameless Plug!!!

Future Classes

- Got the network fever?

- Statistical Analysis of Network Data (CRJ 605) in Spring
    - https://jacobtnyoung.github.io/SAND/
- Network Criminology (CRJ 523) (TBD)
    - https://jacobtnyoung.github.io/NetworkCriminology/

Thank you!!!!

Jacob Young
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https://jacobtnyoung.github.io/