Network Dynamics & Vulnerability

CRJ 523

Network Criminology

Learning Goals

- Understand an explanation of structural diversity in illicit networks.
- Revisit **degree** and **degree centralization**.
- Understand the differences between **error**/**attack** and **homogenous**/**inhomogeneous** in networks.
- Understand **security/efficiency tradeoff**.

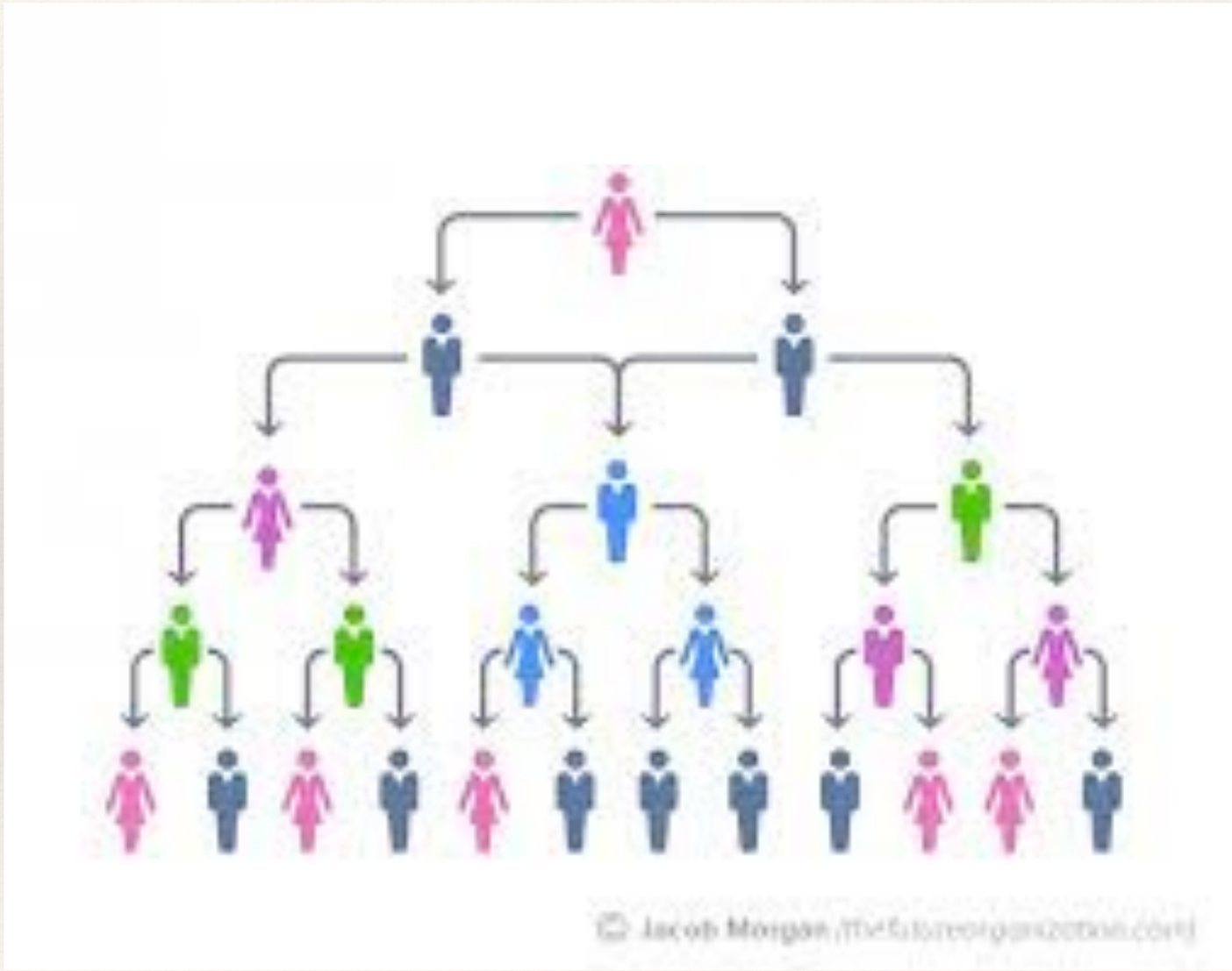
Illicit Networks

- Think about groups like gangs, terrorist organizations, rogue religions sects, etc…
  - Groups in which activity violates law or norms and there is organized activity to prevent the behavior.
    - **Illicit networks**

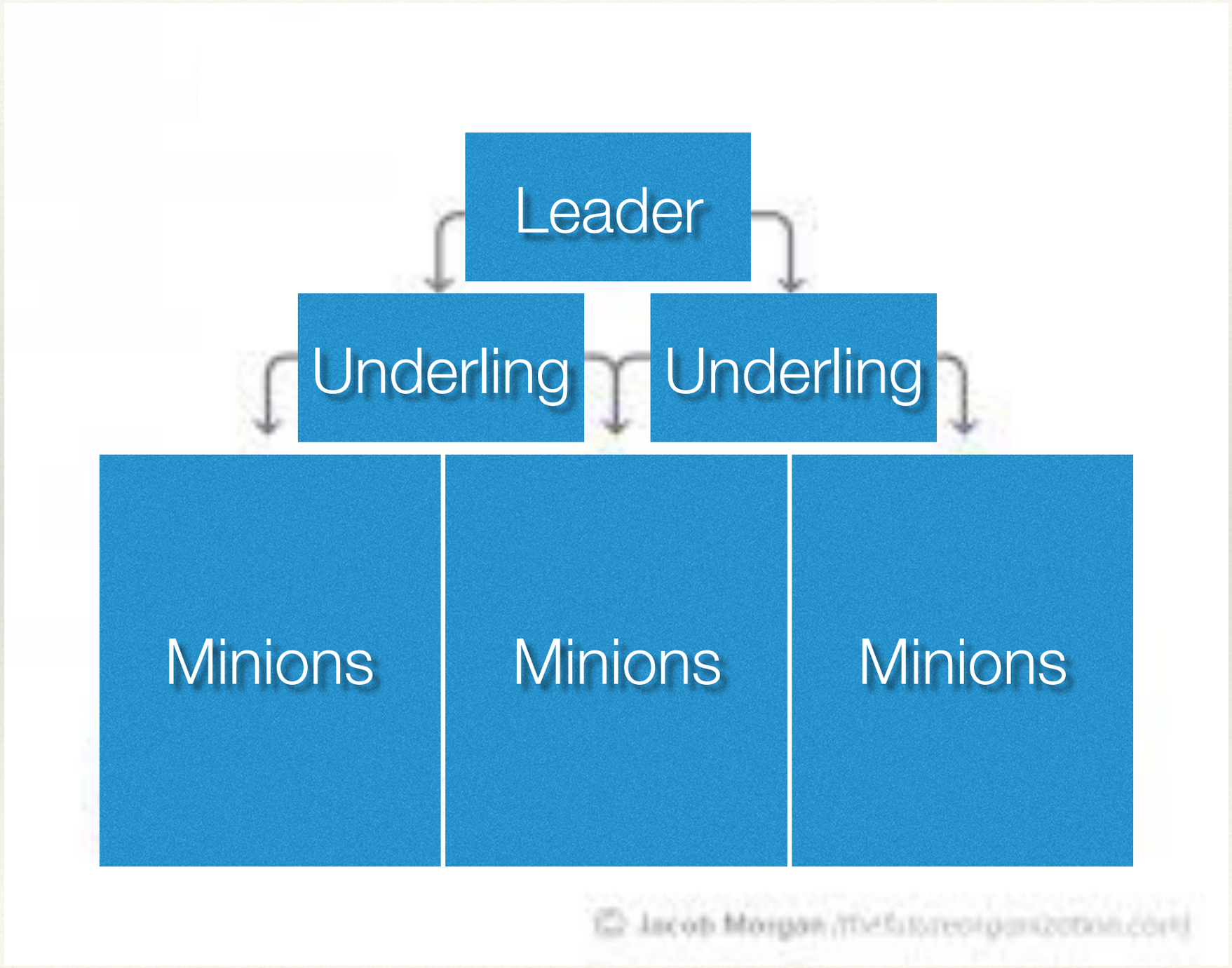
- A natural question: *how are they organized*?

Illicit Networks

- Classical sociological theory (e.g. Georg Simmel) and contemporary "common sense" accounts tend to emphasize a **hierarchical structure.**



Illicit Networks



Illicit Networks

- Erickson (1981)
  - *Actually*…it depends!
    - Empirically there is **variation** in the organization of illicit groups.
      - Some are **hierarchical**, whereas some are **decentralized**.

- Question: why do "secret societies" variety in their organizational structure?

Illicit Networks

- Erickson (1981)
  - **Secret Societies**
    - "persisting pattern of relationships which directly or indirectly links the participants in related secret activities" (p. 189)
      - Activities involve risk ("secret")
      - Ties are durable ("society")

- **Risk** makes the behavior of individuals in these settings *different* than other organizations.

Illicit Networks

- Example:
  - You buy a wicked awesome skeletor toy from the store, only to find it is broken!
    - *What can you do about it?*

Illicit Networks

- Example:
  - You buy a wicked awesome bag of crack, only to find it is baby formula!
  - *What can you do about it?*

Illicit Networks

- Example:
  - You ask your friend to join your basket weaving group, and they tell a bunch of people you are into basket weaving!
  - *Do you care?*

Illicit Networks

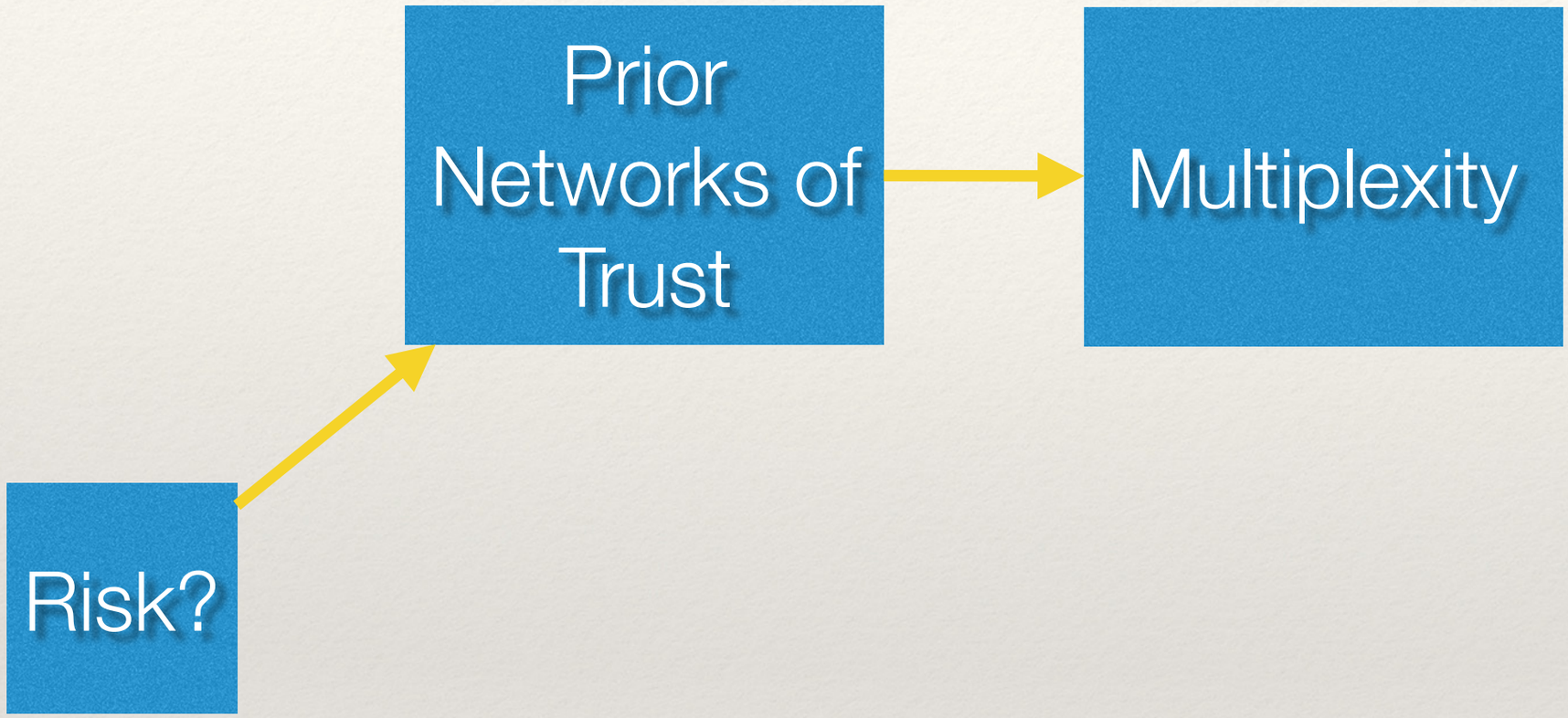
- Example:
  - You tell your friend your basket weaving group has committed several murders, and they tell a bunch of people you are into murdering people (and basket weaving)!

  - *Do you care?*

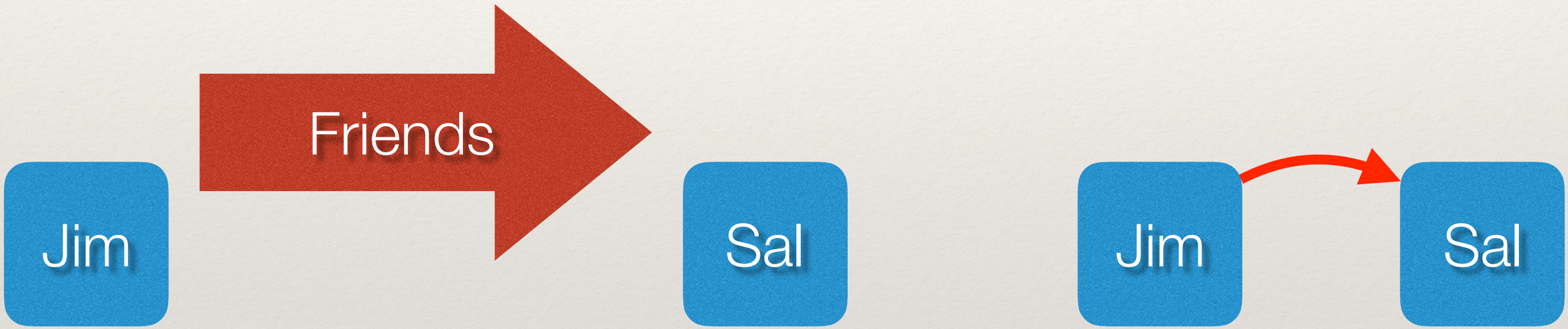
Illicit Networks

- Erickson (1981)
  - Proposes a "theory of networks"
    - The presence of **risk** creates variation in the structure of groups.
    - Explained by:
      - Prior trust networks (multiplexity via entrainment)
      - Locus of control of recruitment
      - Command of resources

Explaining Network Structure

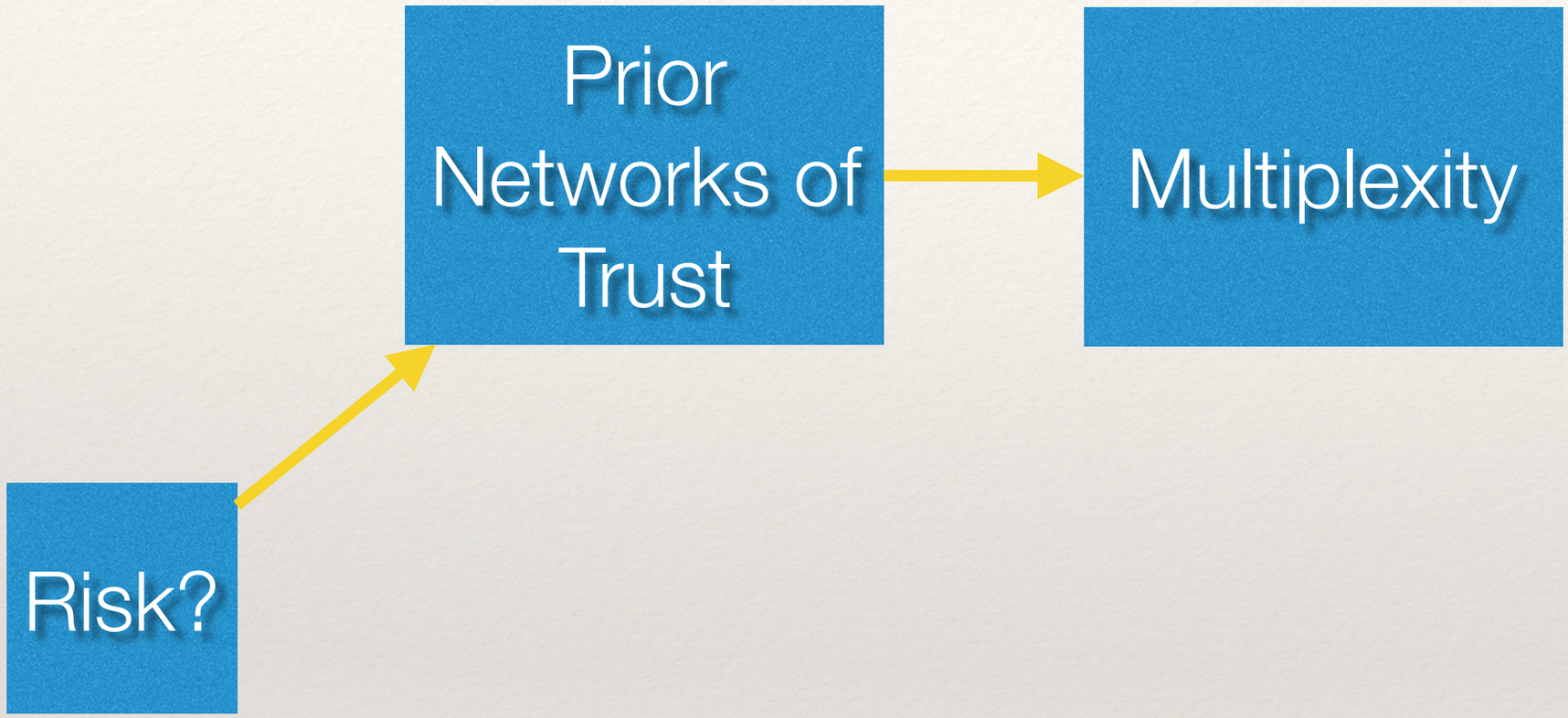


Entrainment

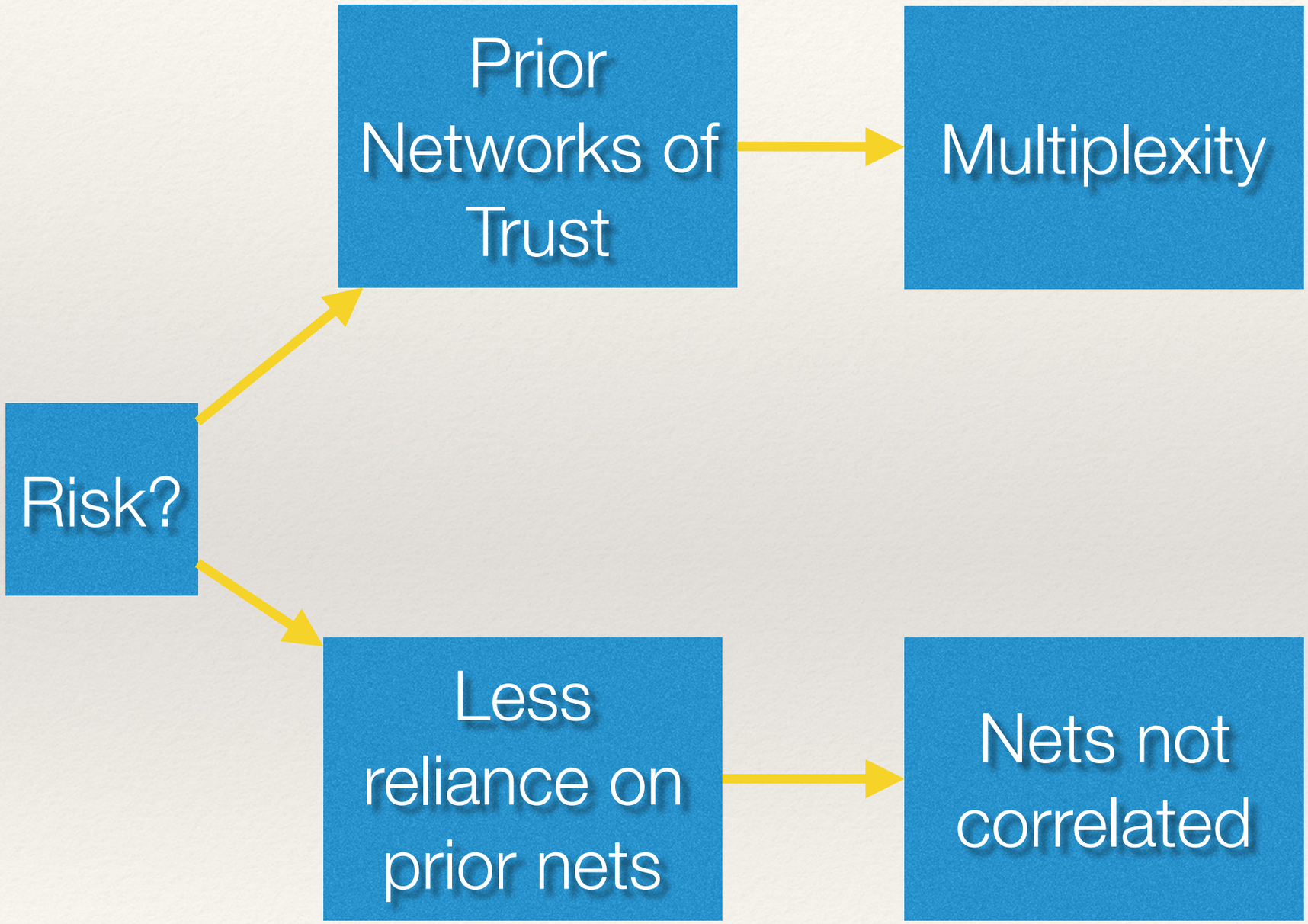


Entrainment

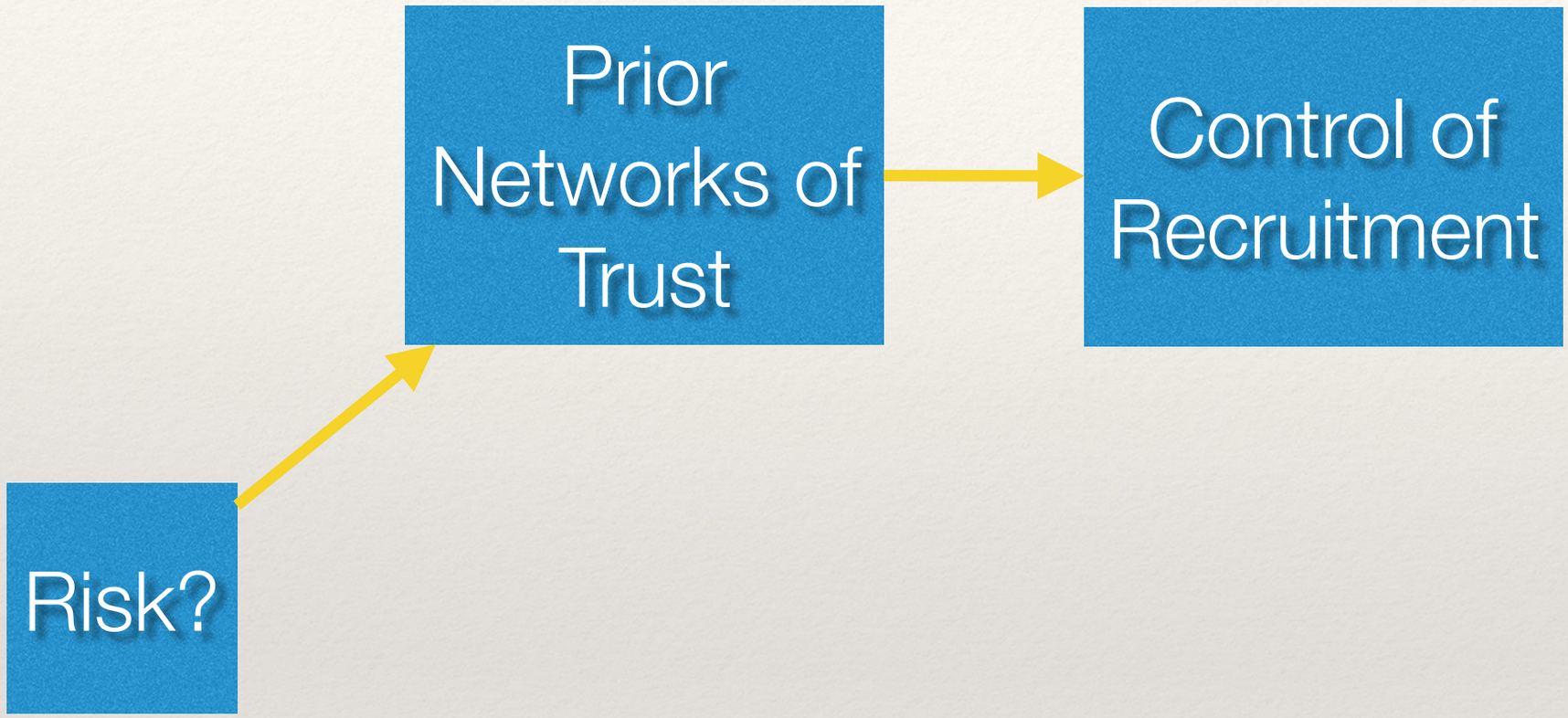
Explaining Network Structure



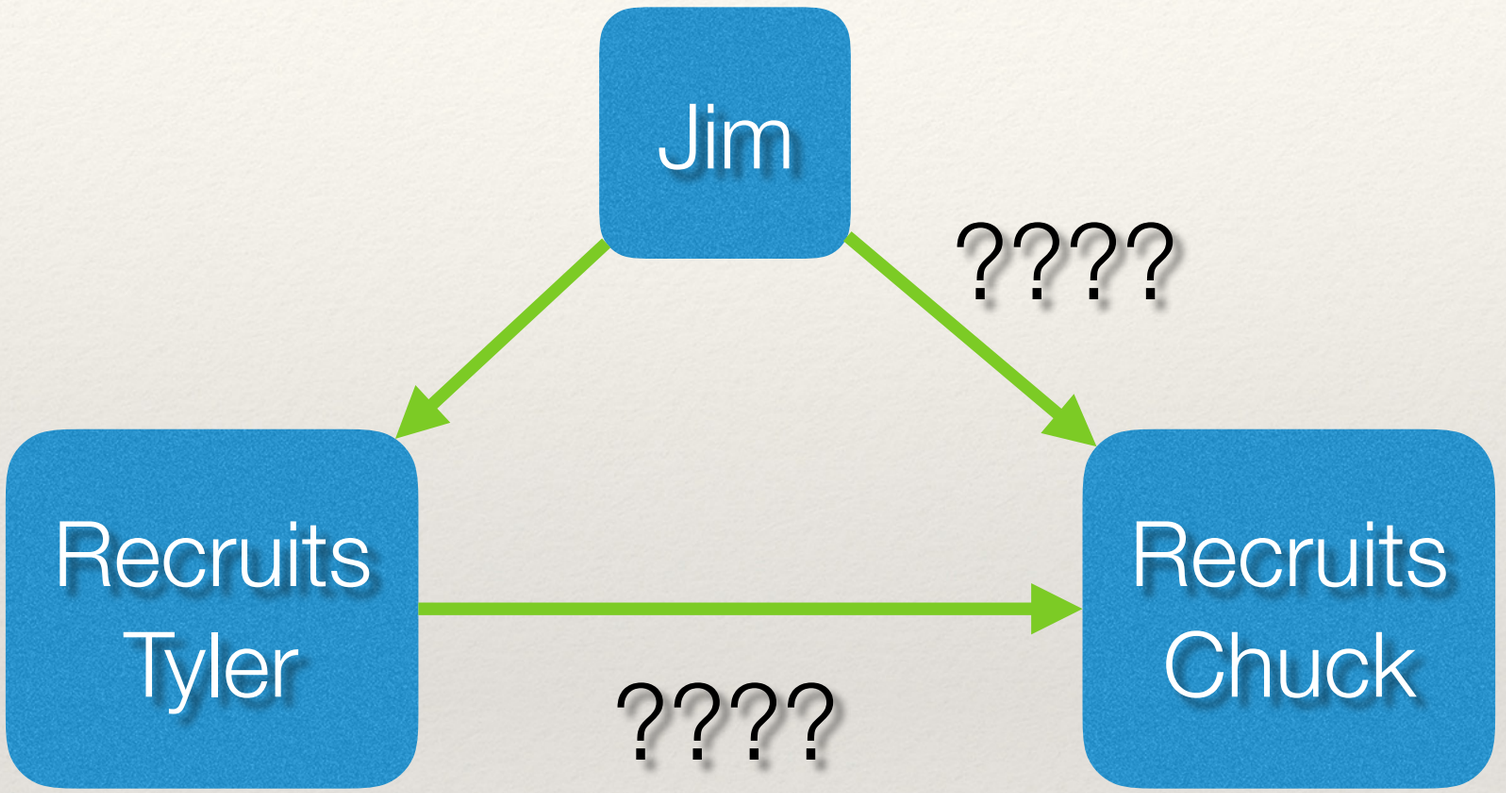
Explaining Network Structure



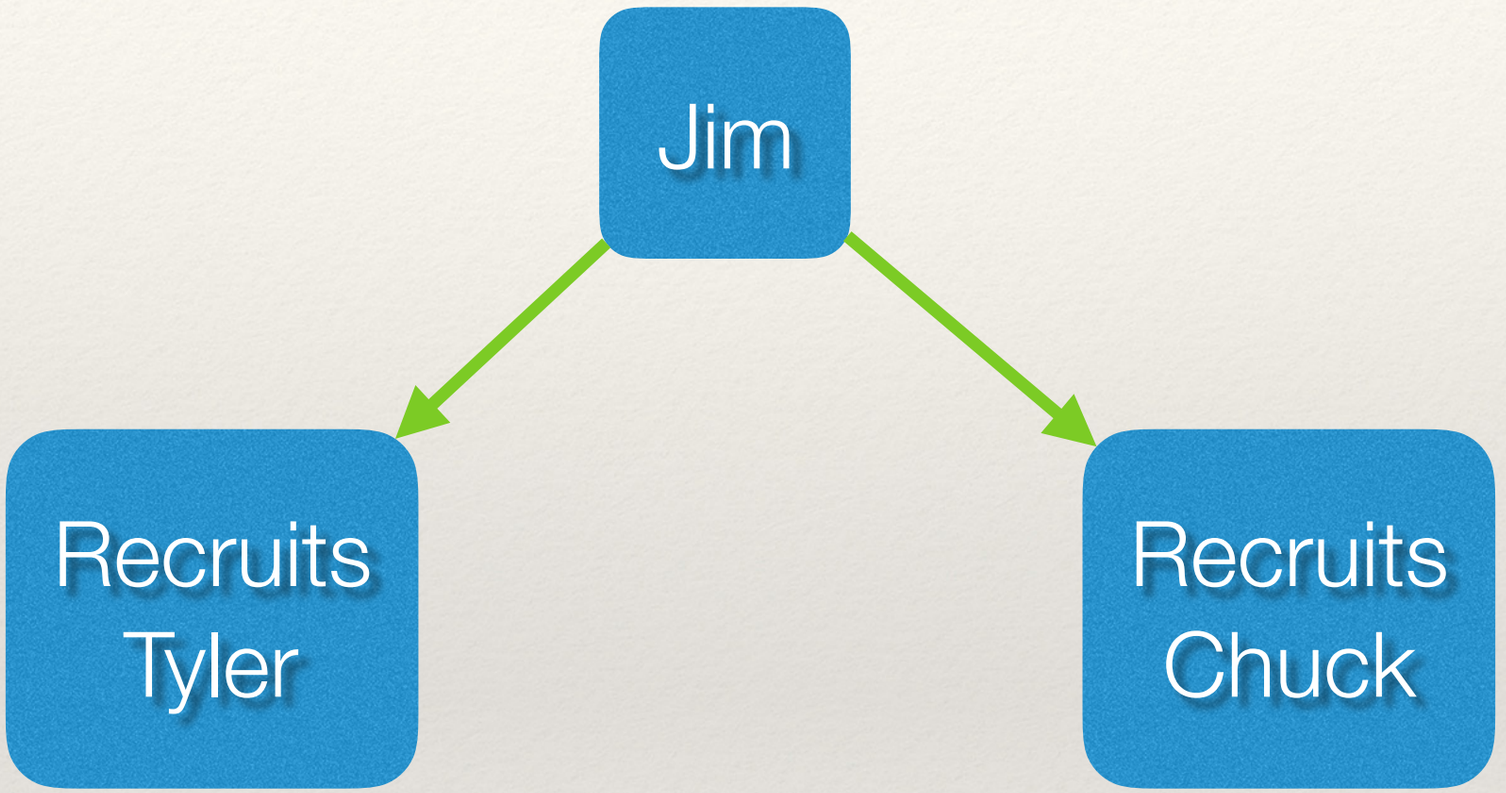
Explaining Network Structure



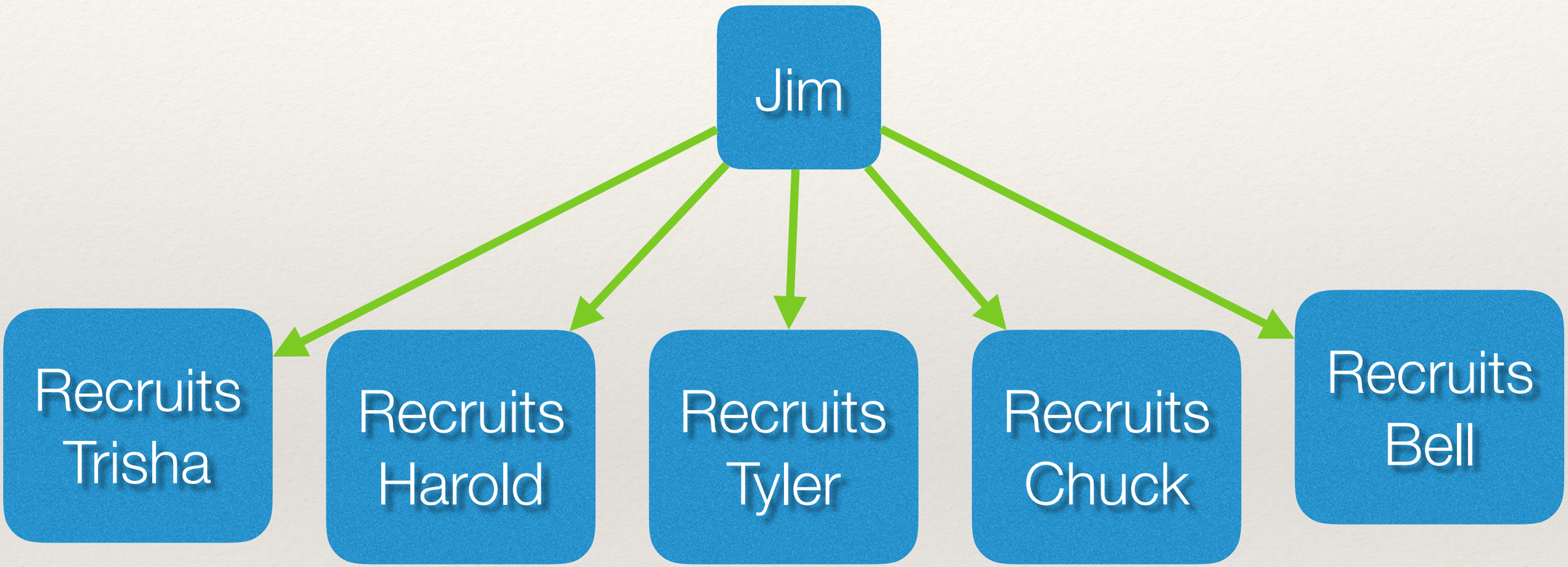
Illicit Networks



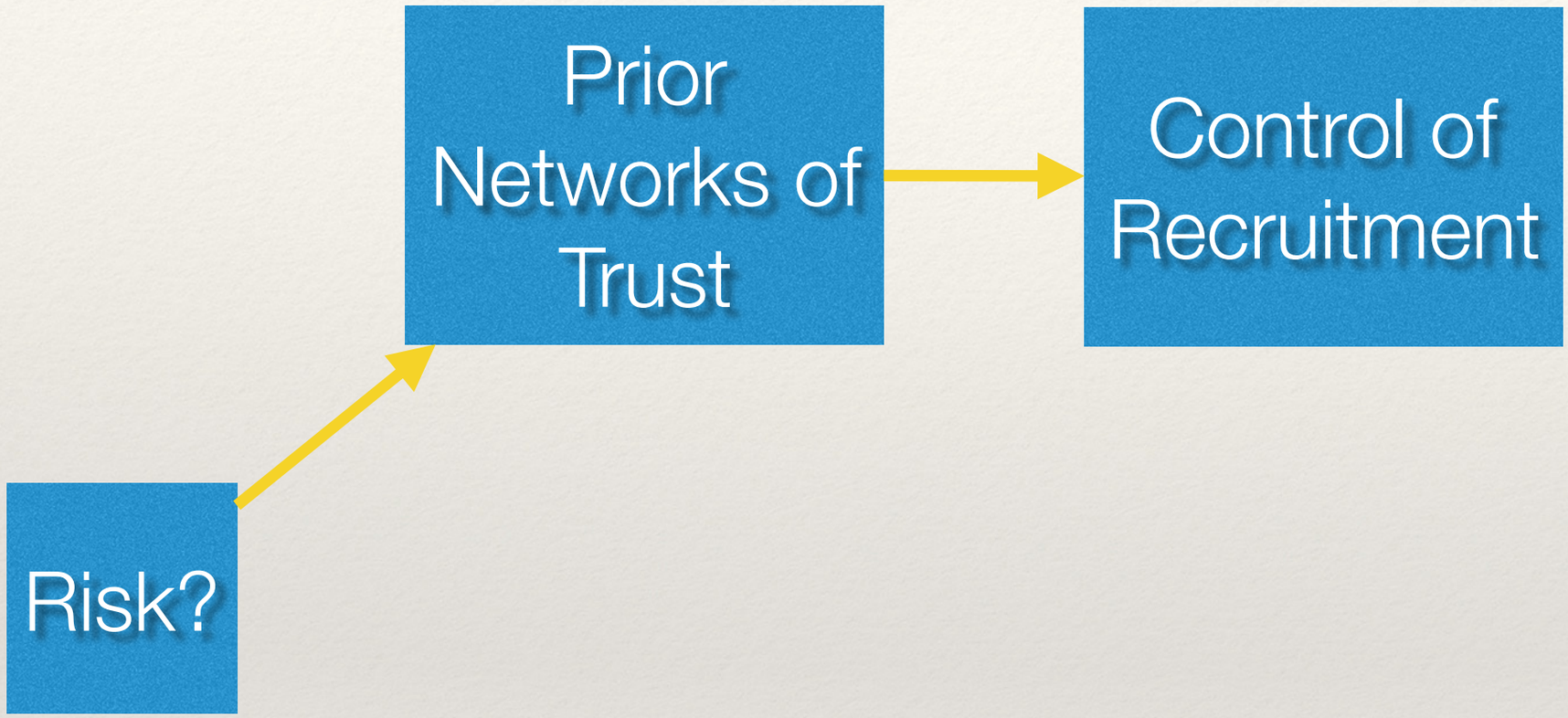
Illicit Networks



Hierarchical (Centralized) Structure



Explaining Network Structure



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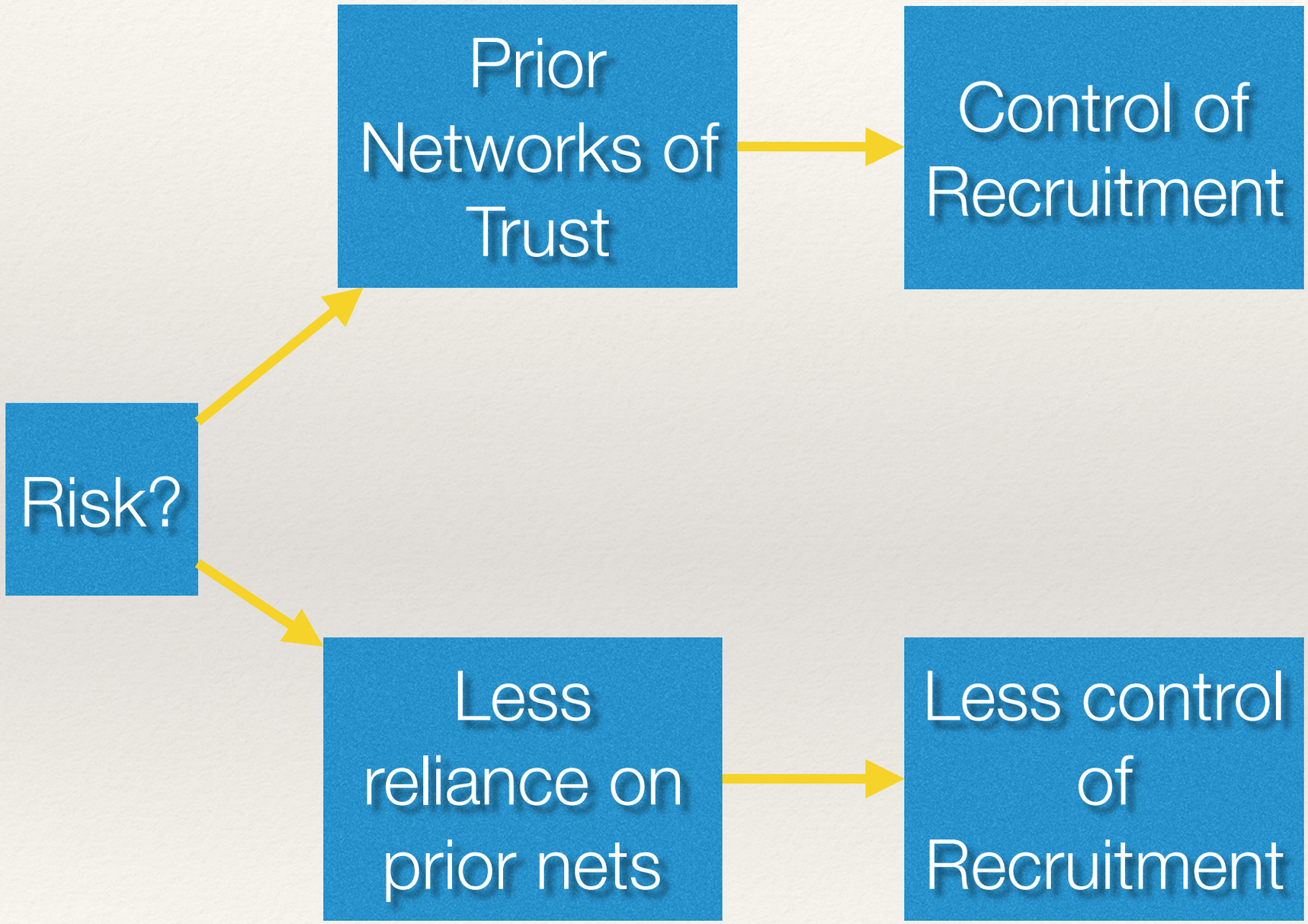
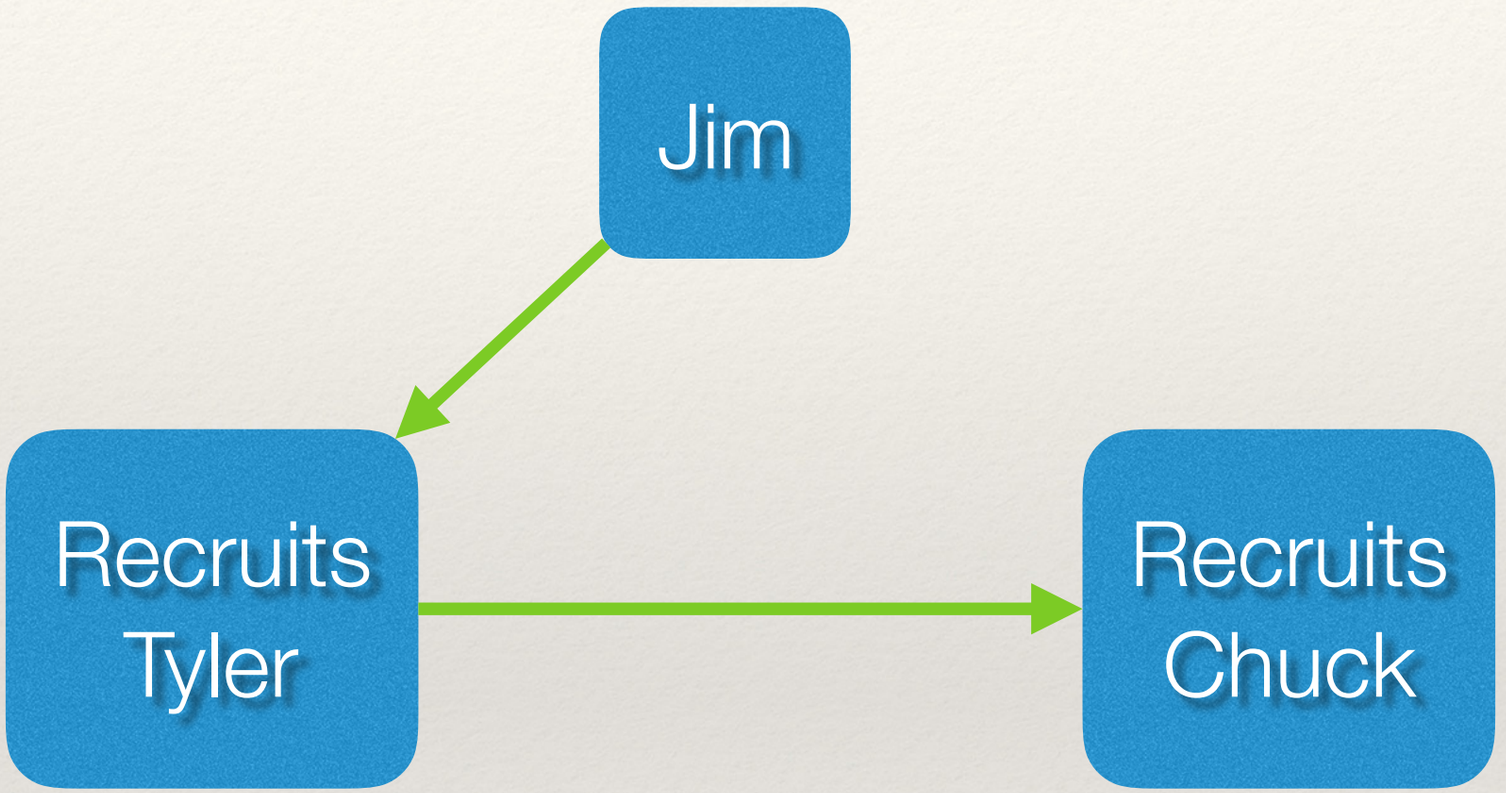
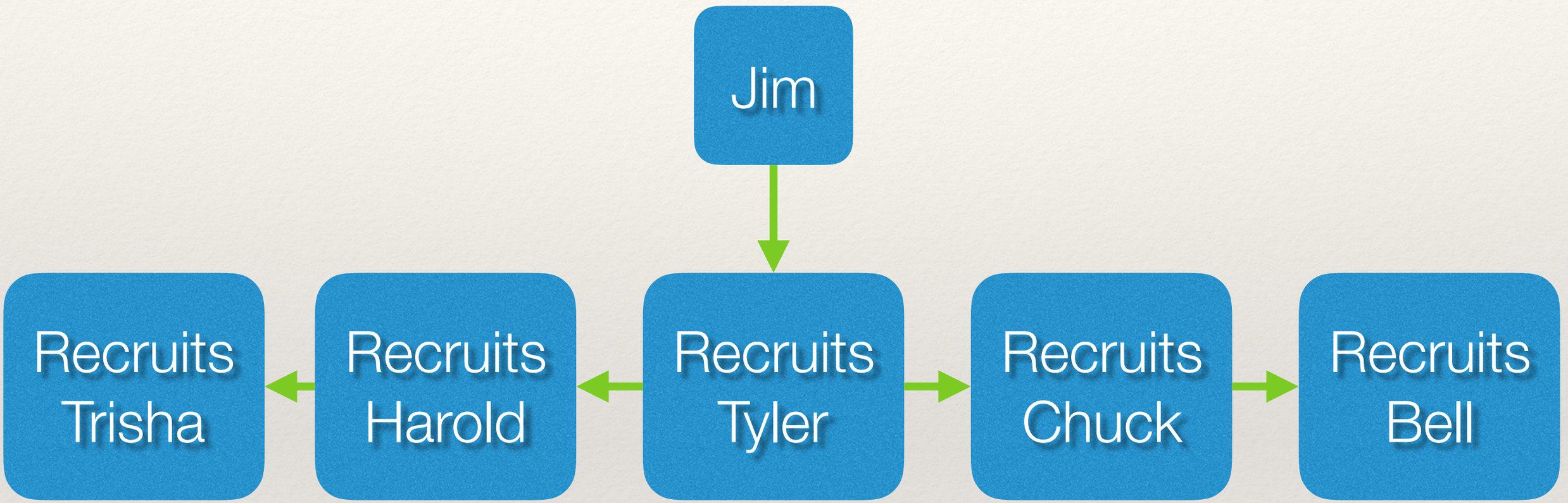


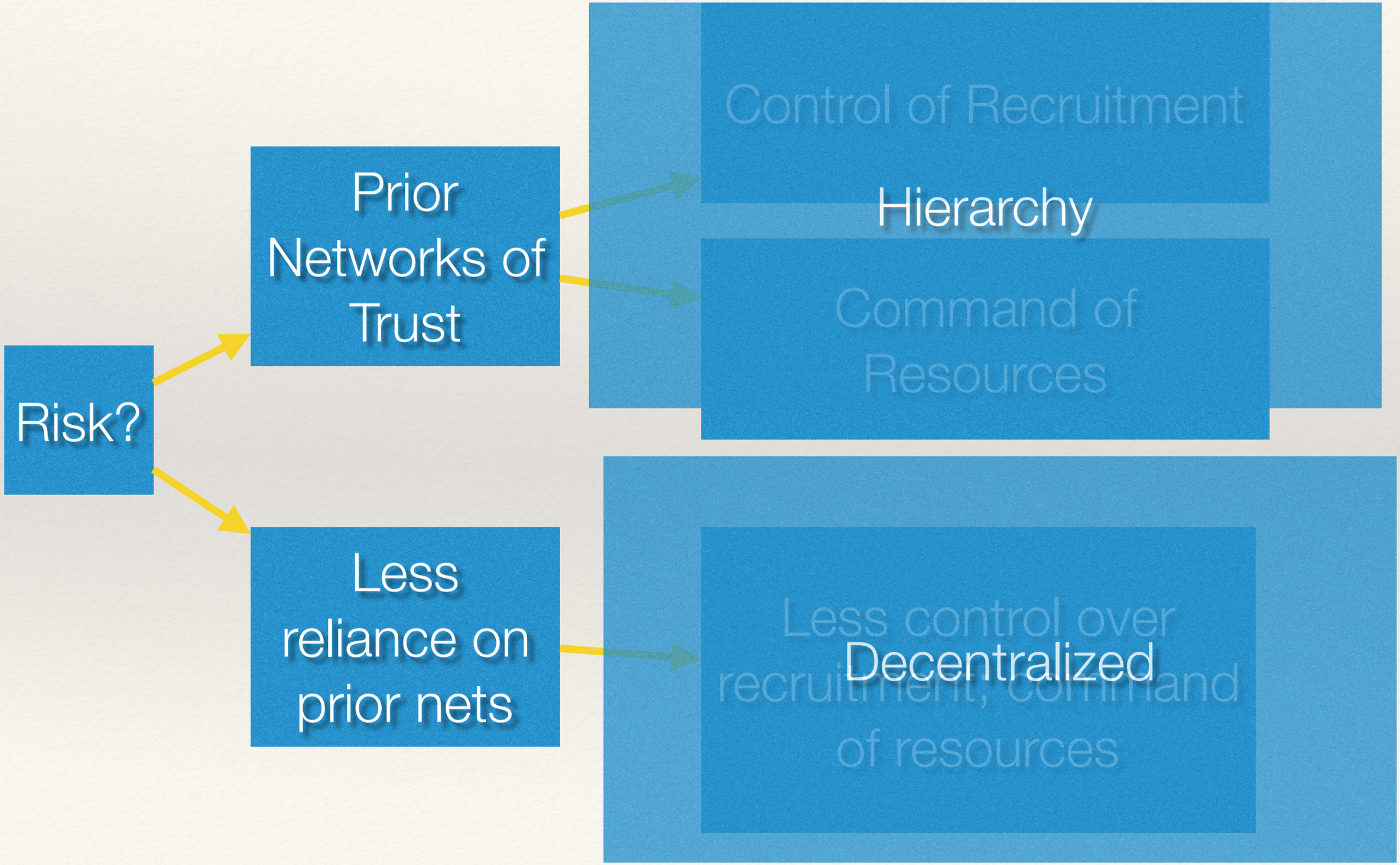
Illicit Networks



Decentralized Structure



Explaining Network Structure



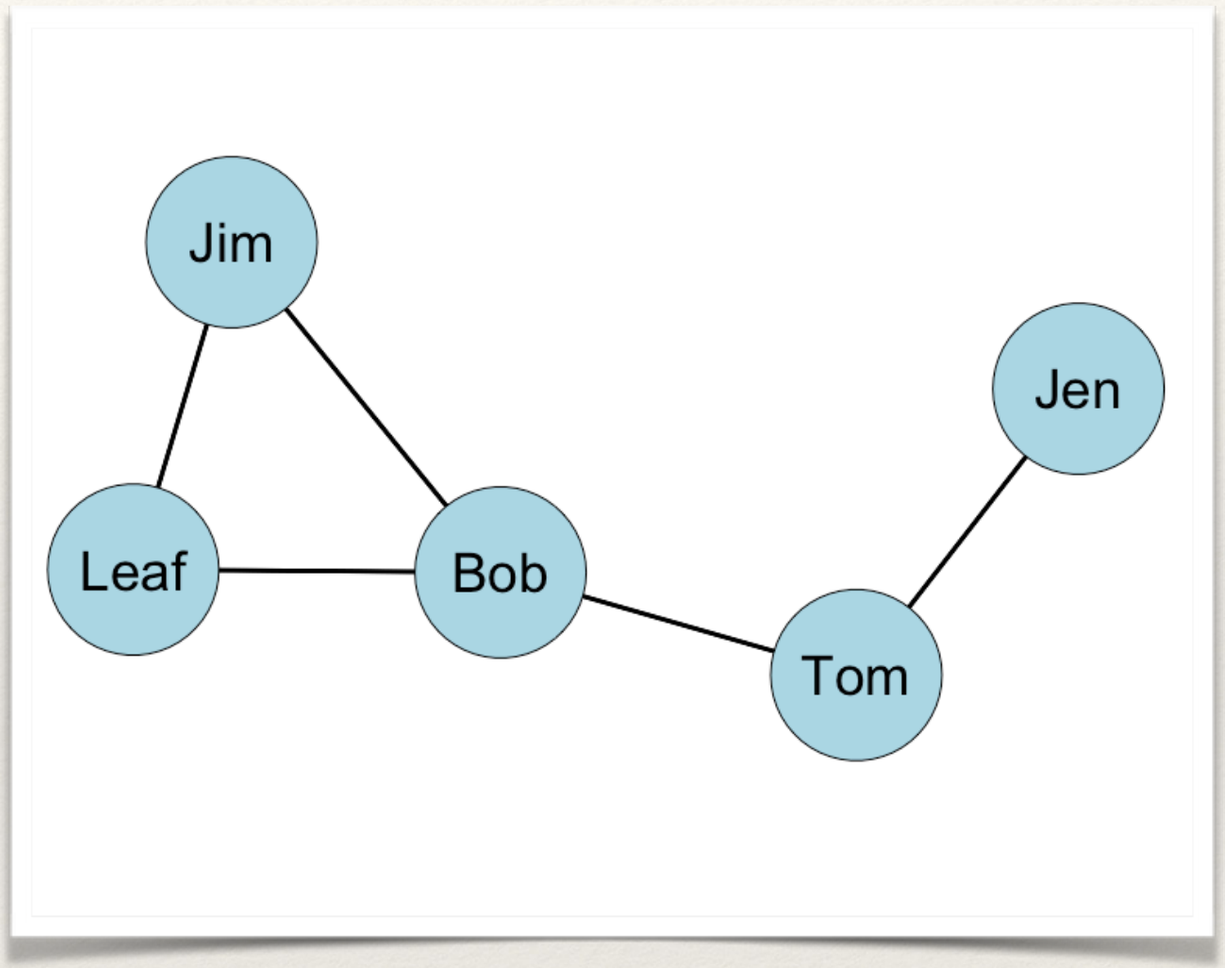
Illicit Networks

- Erickson (1981)
  - Hierarchy then has reciprocal effects:
    - Increased control of recruitment
    - Increased command of resources
      - *Thereby making the network more hierarchical*.

Remember Degree Centrality?

Degree

- In an undirected binary graph, *degree* measures the extent to which a node connects to all other nodes in a social network.



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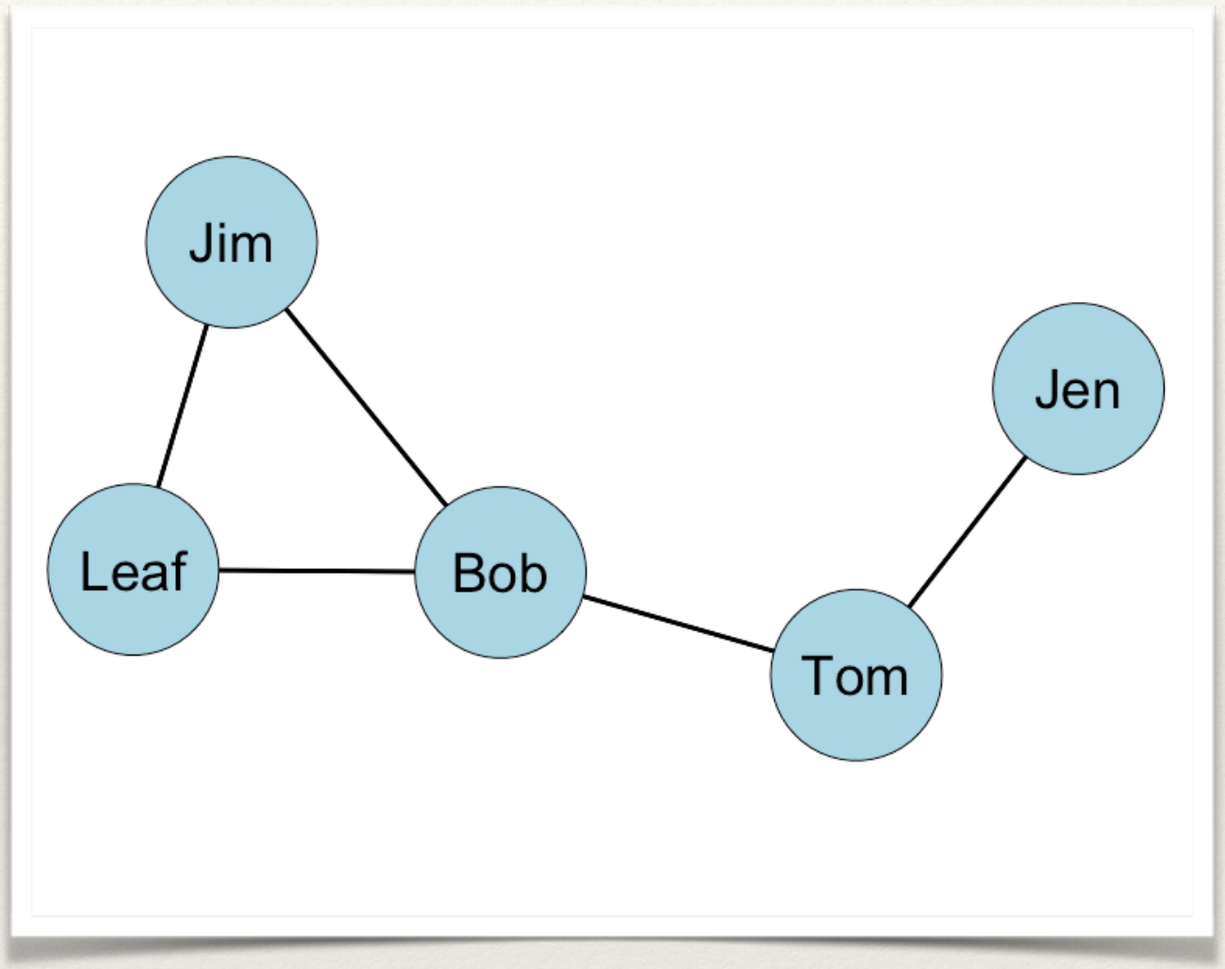


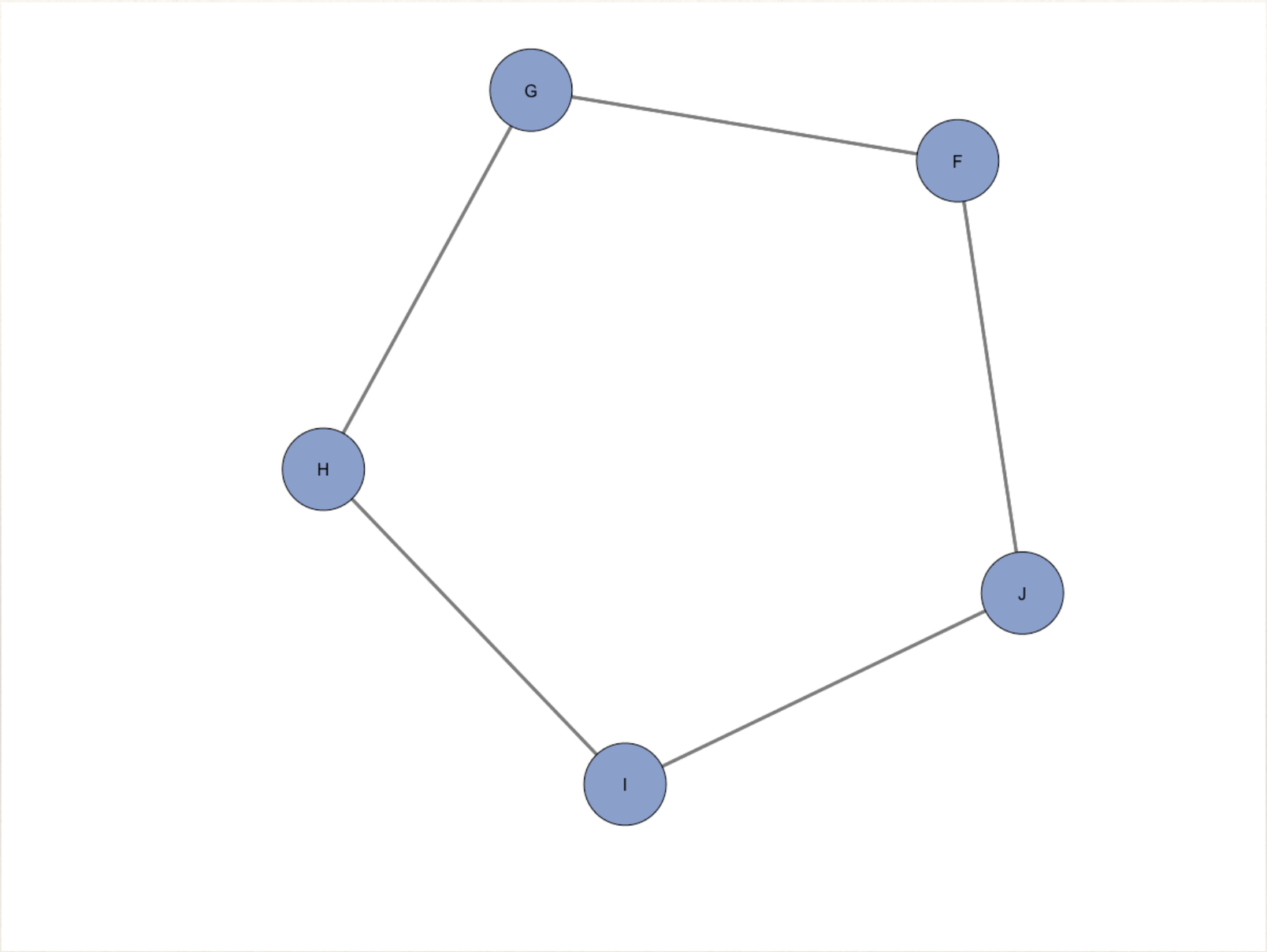
What is the degree for each node in this graph?

Degree

- 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?*

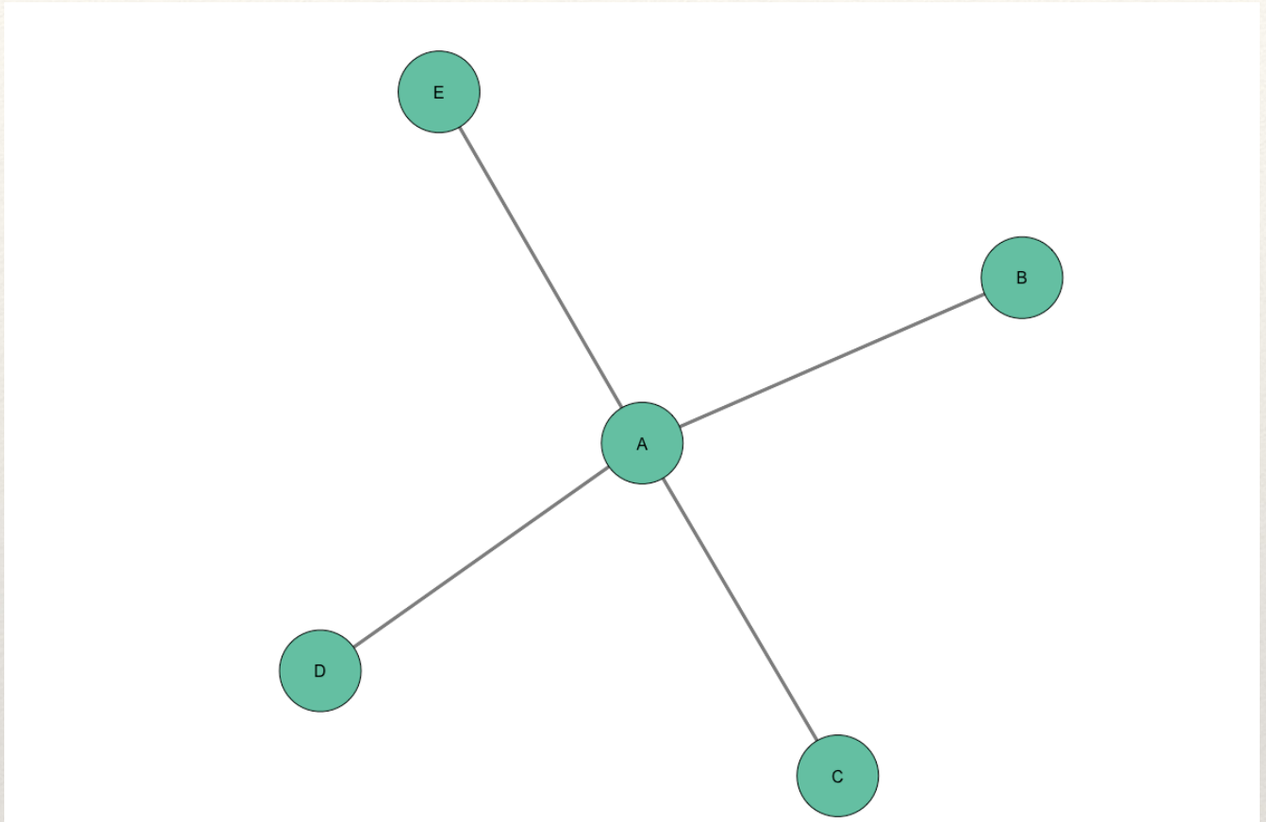
Degree Centralization

- We can also calculate how centralized the graph itself is.
  - *Degree centralization* measures the extent to which the actors in a social network differ from one another in their individual degree centralities.
  - When degree centrality is evenly dispersed, degree *centralization* will be 0.

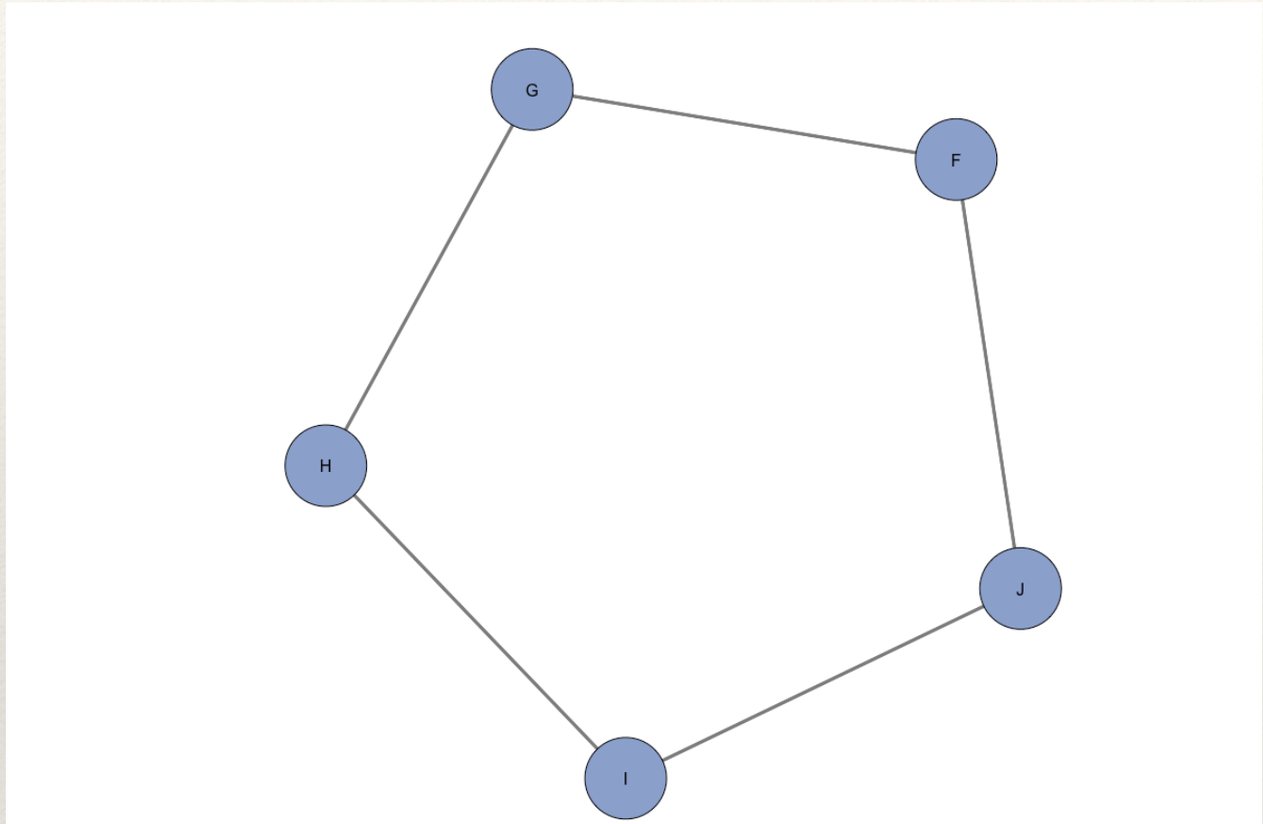

G
F
H
J
I

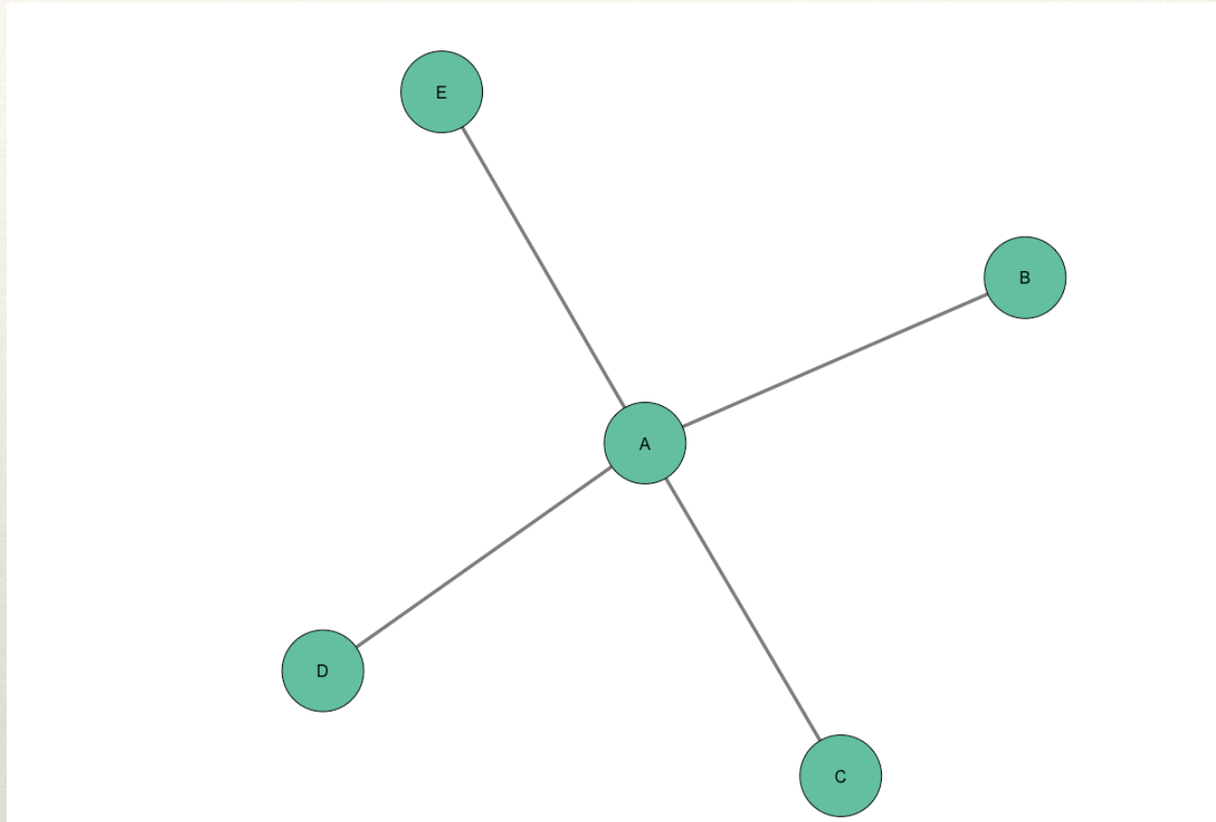
Degree Centralization

- When there is considerable inequality in the actor degrees, degree *centralization* will be close to 1.
  - Thus, closer to 1 indicates that the graph is hierarchically structured.


E
B
A
D
C

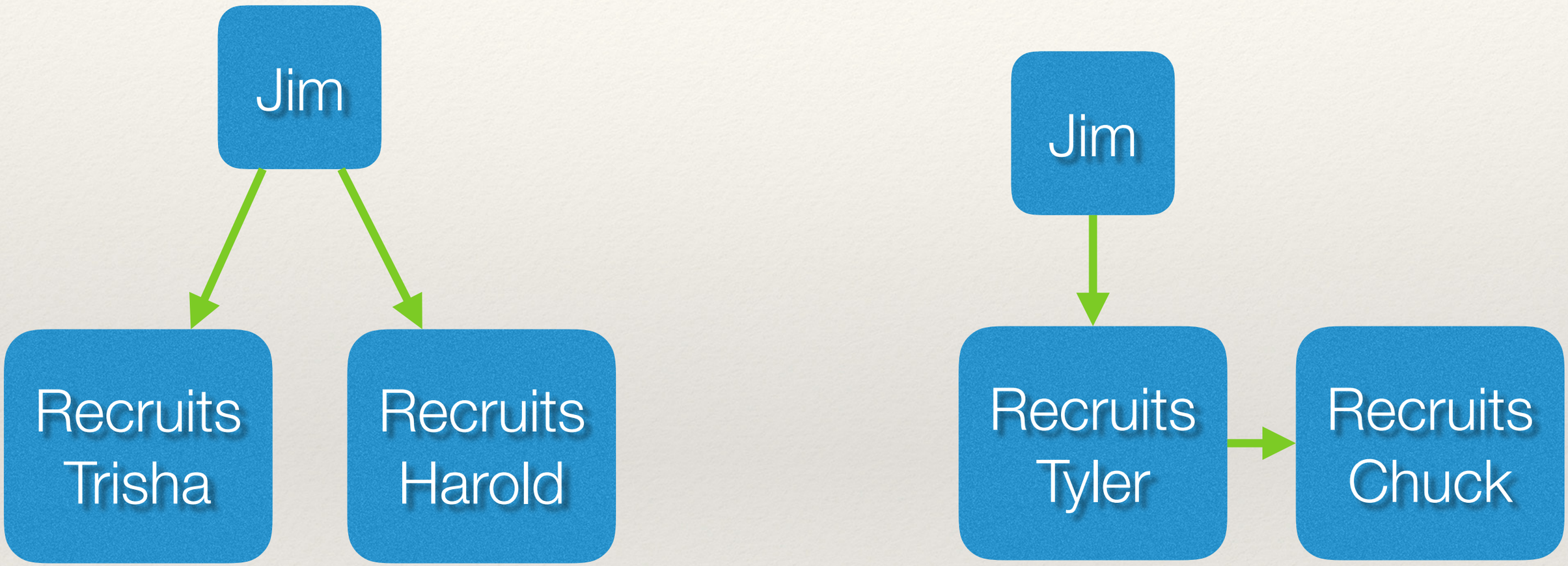
*The **degree distribution** is more equal here*





*The **degree distribution** is more <u>unequal</u> here*

Network Vulnerability

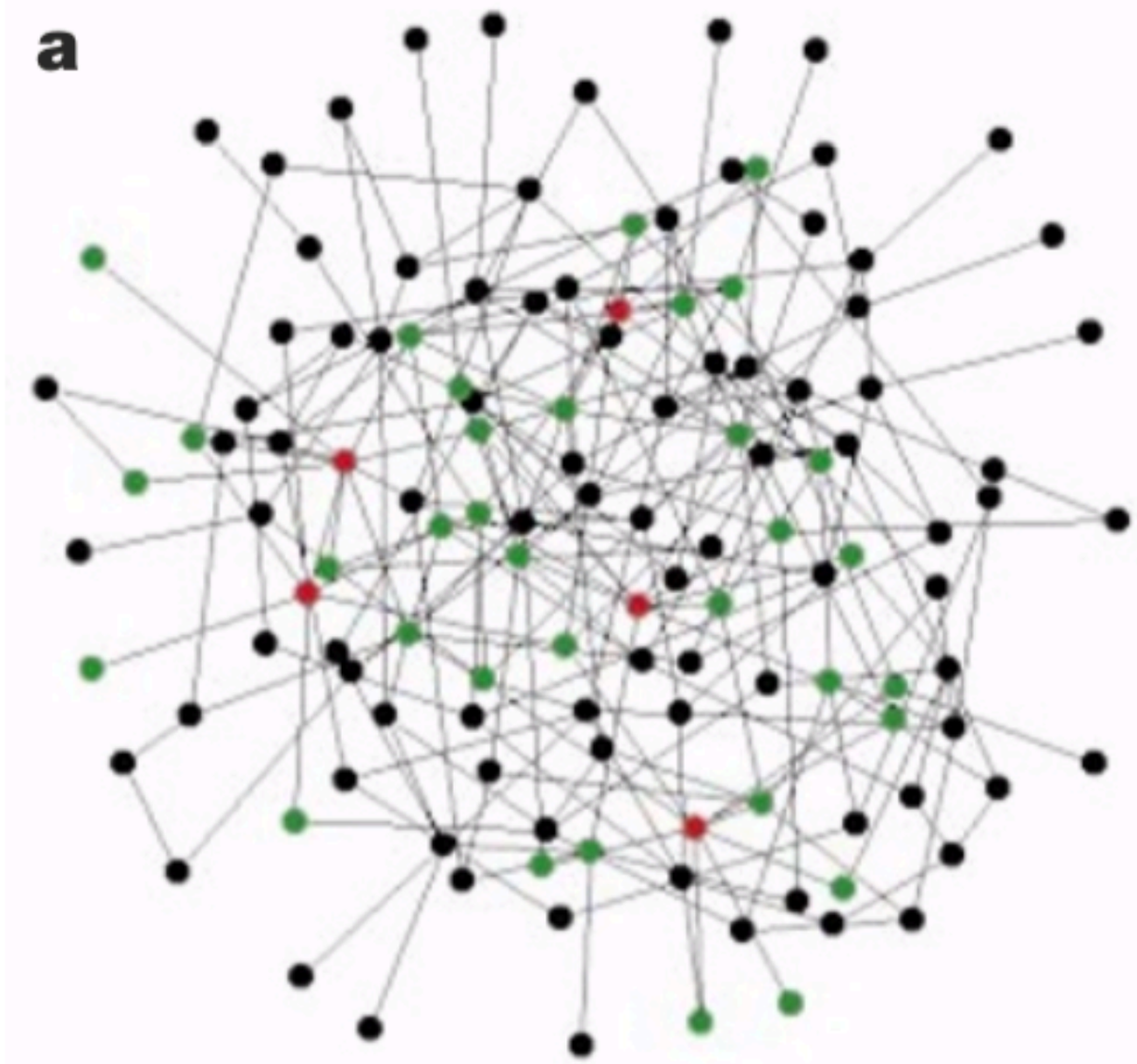


Which network is more
vulnerable?

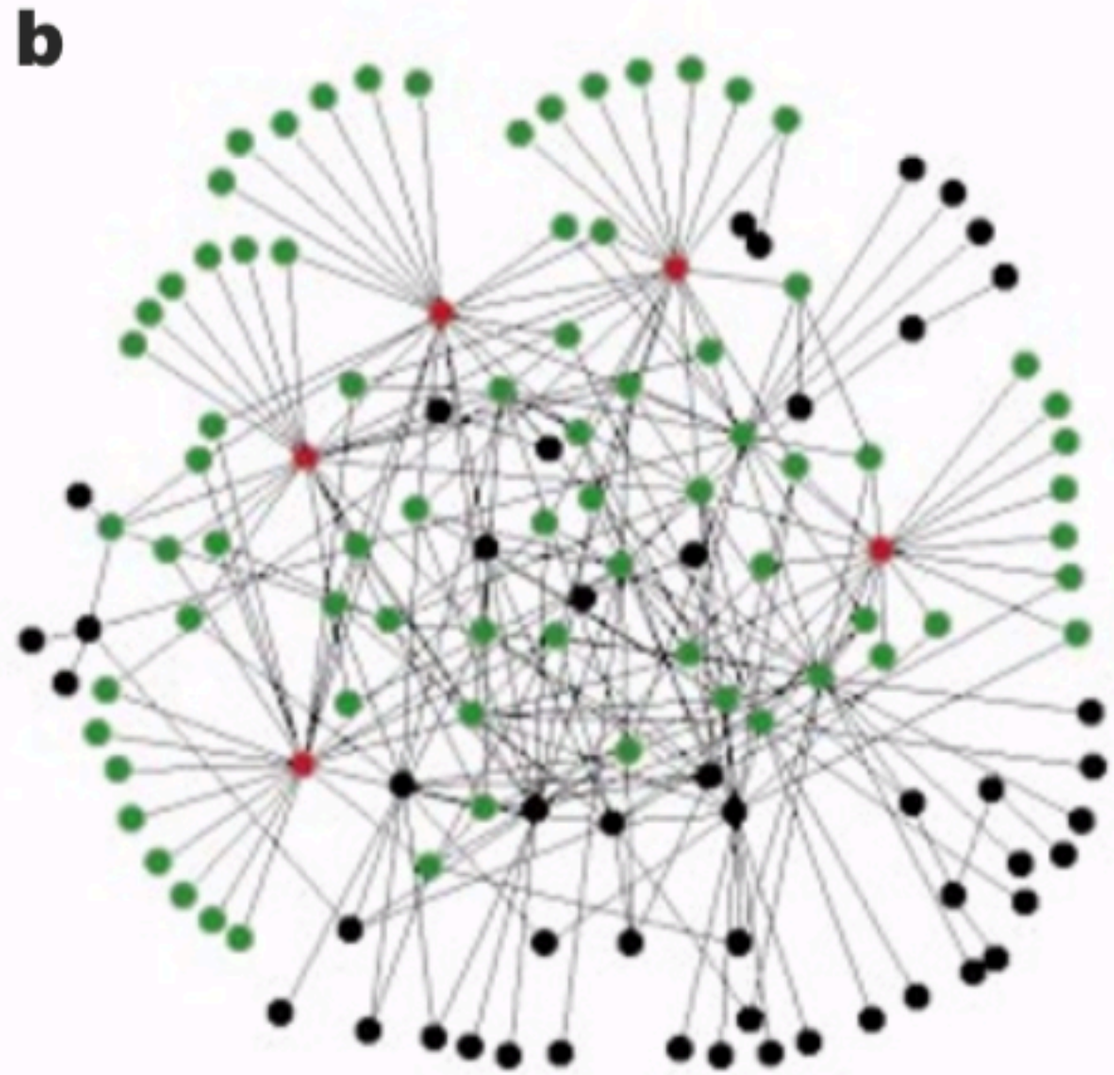
Network Vulnerability

- Albert, Jeong, and Barabasi (2000)
- It depends…
  - Is it **homogenous** (exponential / decentralized) or **inhomogeneous** (scale-free / centralized)?

Network Vulnerability



Degree ***homogenous*** *network*



Degree ***inhomogenous*** *network*

Network Vulnerability

- Albert, Jeong, and Barabasi (2000)
  - It depends…
    - Is it an **error** or an **attack**?

Network Vulnerability

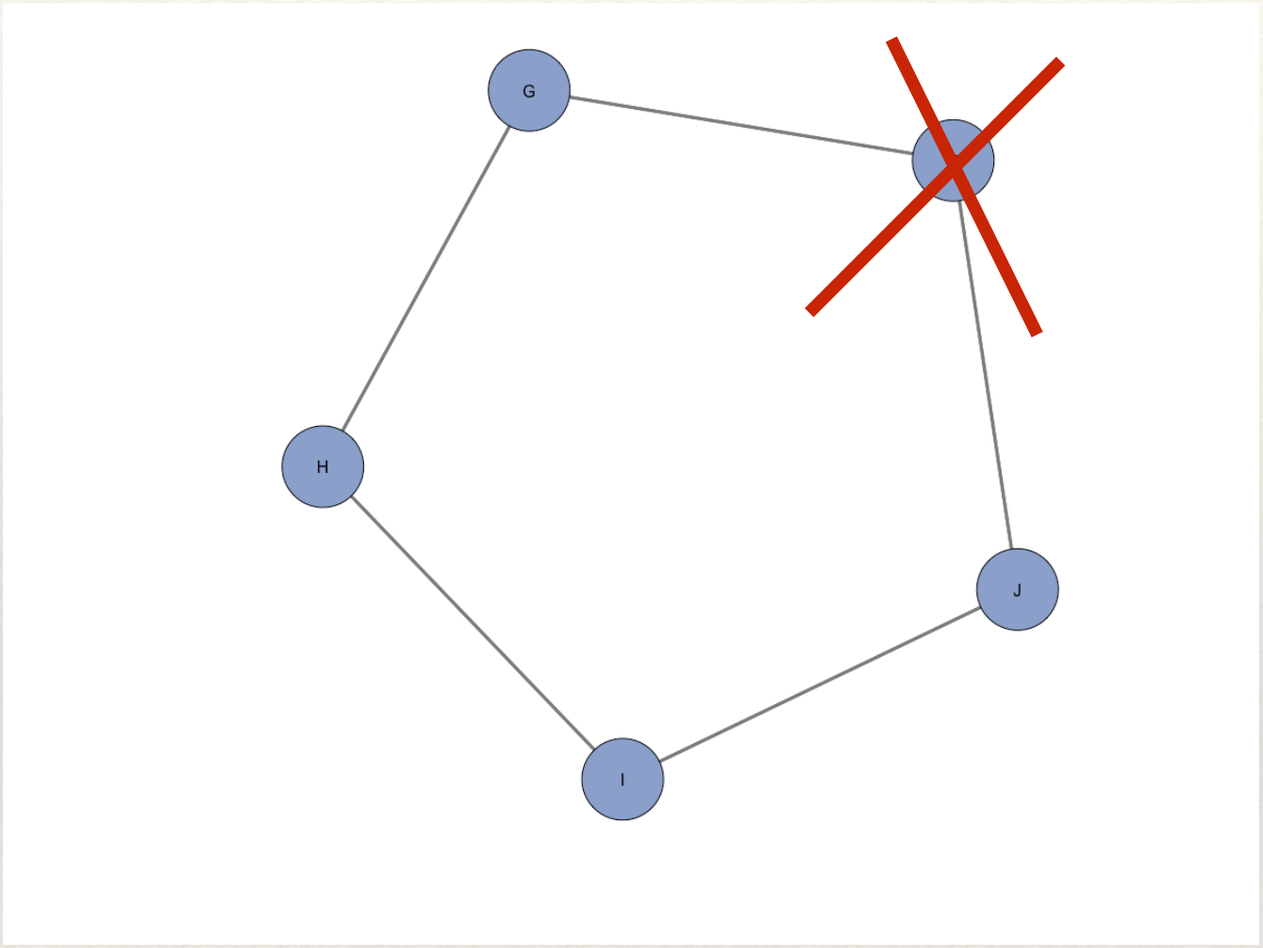
- Albert, Jeong, and Barabasi (2000)
  - Homogenous networks
    - Vulnerable to errors, less vulnerable to attacks.
  - Inhomogenous networks
    - Less vulnerable to errors, vulnerable to attacks.

- ***Why?***

Network Vulnerability

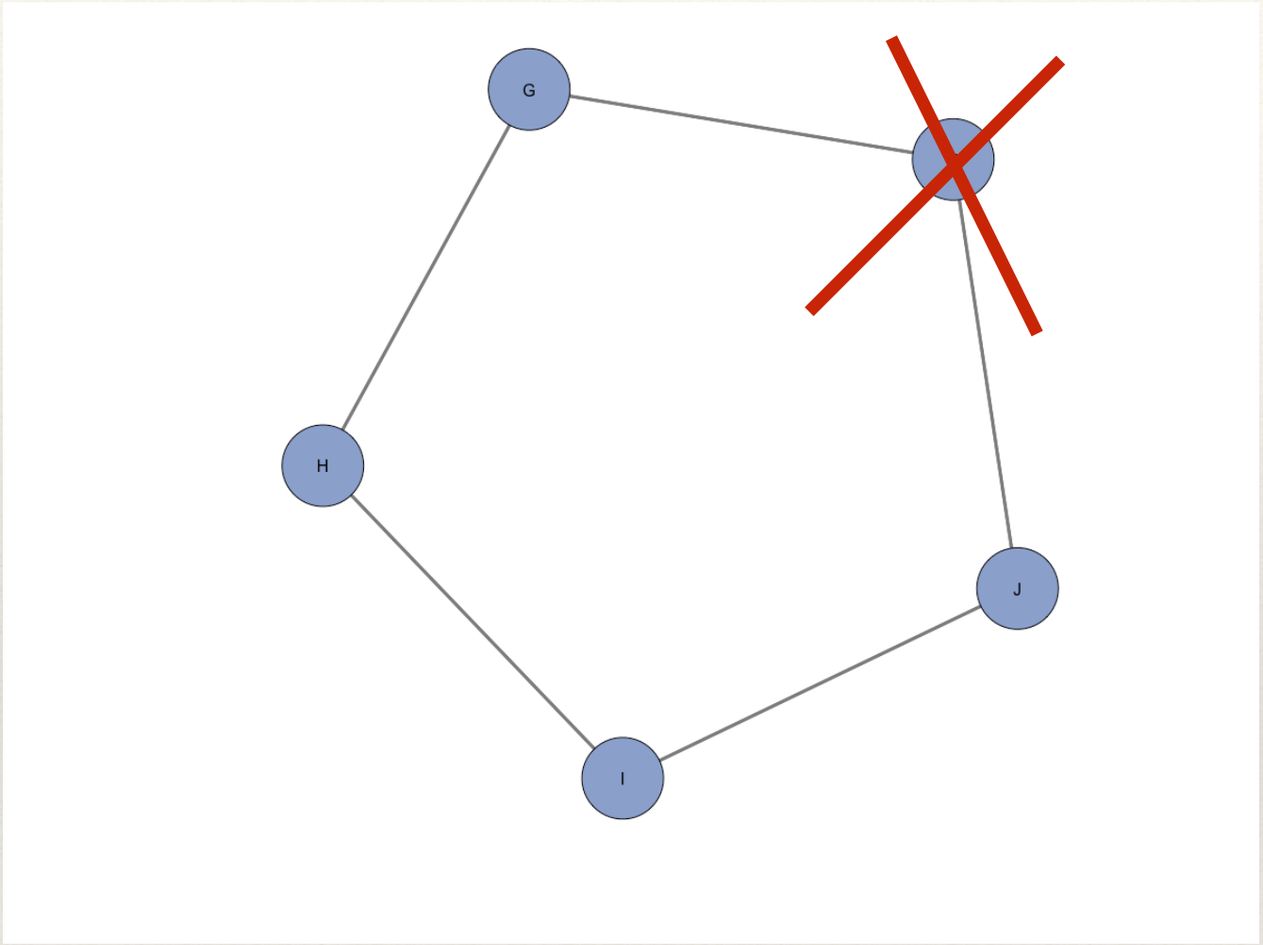
- Albert, Jeong, and Barabasi (2000)
  - Inhomogeneity **INCREASES** connectivity.
    - It decreases the diameter (average shortest path).

What happens to the graph if this node experiences an error?



How does G reach J?

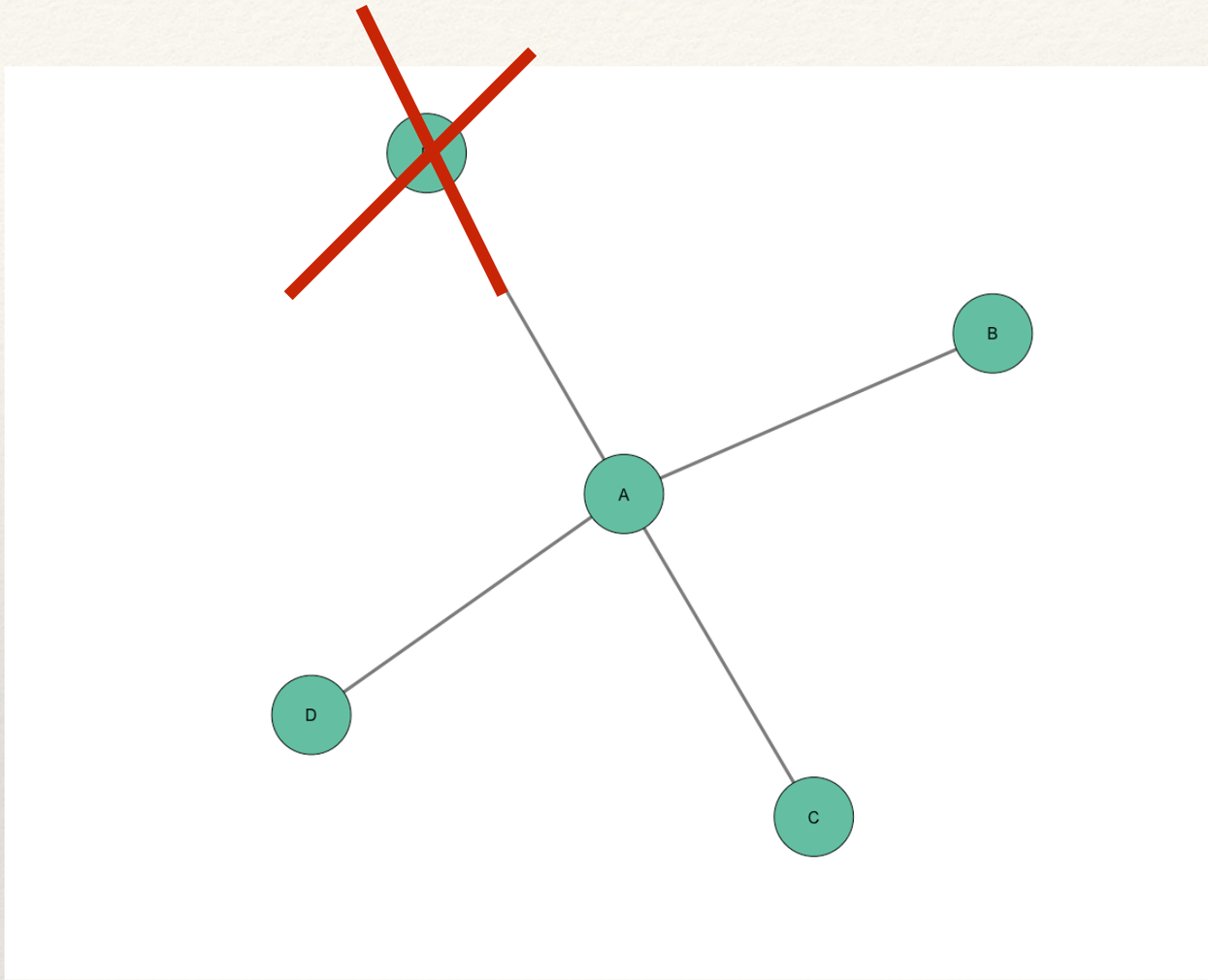
What happens to the graph if this node experiences an error?



Why?

The average path length increases.

What happens to the graph if this node experiences an error?



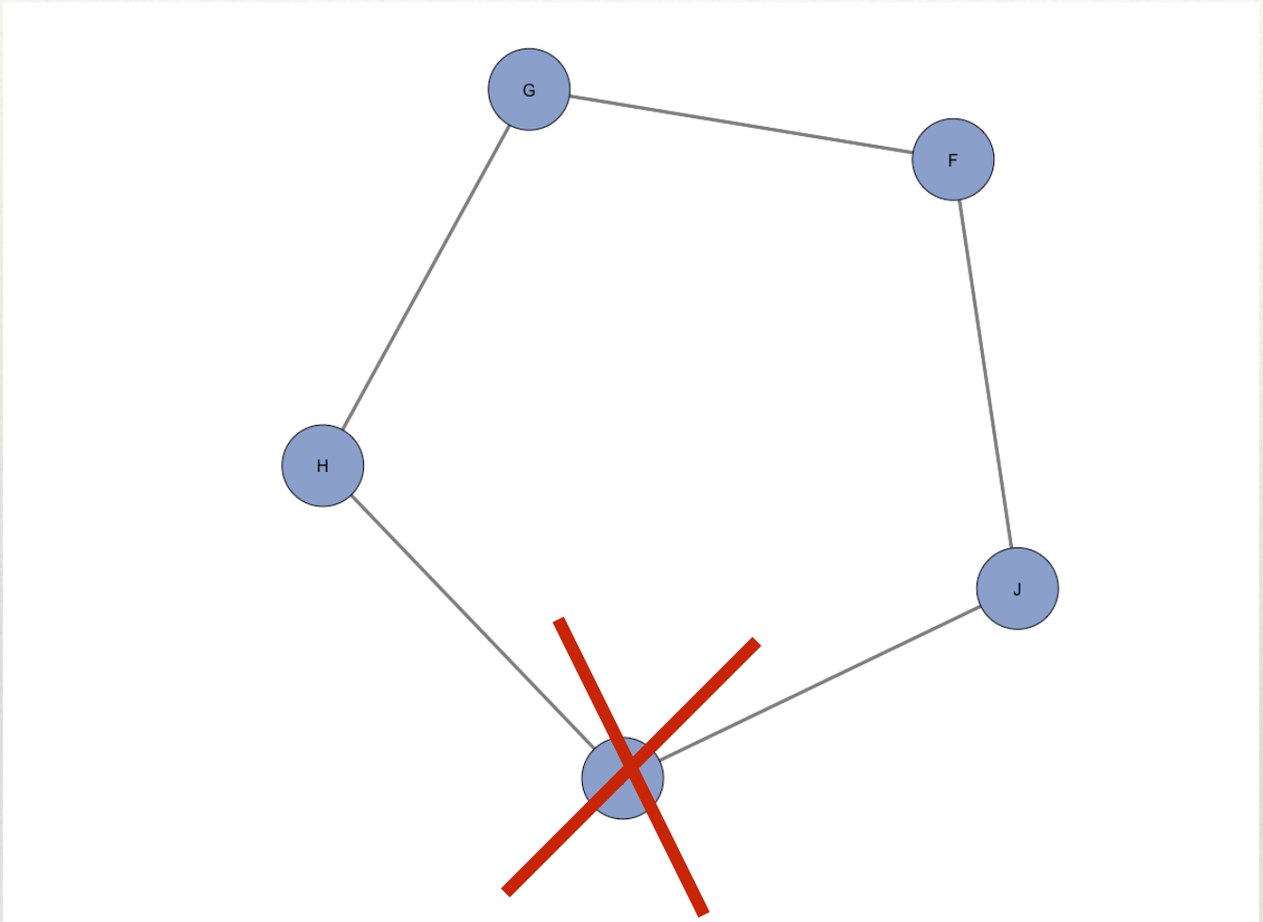
Why?

The average path length doesn't change.

Network Vulnerability

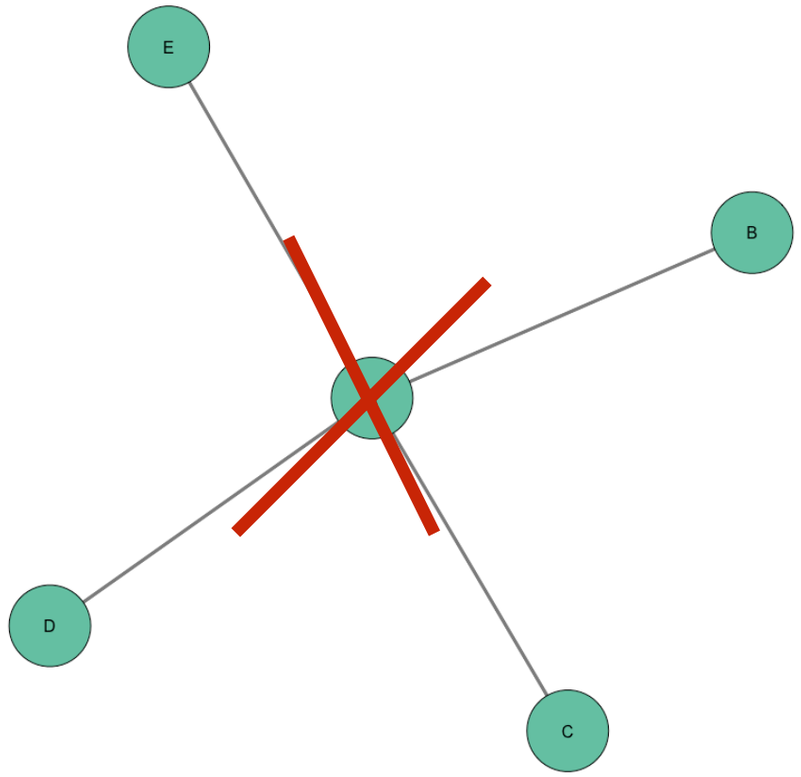
- Albert, Jeong, and Barabasi (2000)
- **BUT!!!…**
  - The high connectivity is what creates vulnerability to attack.

What happens to the graph if this node experiences an **<u>attack</u>**?



Why?

What happens to the graph if this node experiences an **attack**?



Why?

Network Vulnerability

- Albert, Jeong, and Barabasi (2000)
- Network vulnerability depends on:
  - The degree distribution (homogenous vs. inhomogeneous)
  - The type of action (error vs. attack)

Remember this?

- Aral & Alstyne (2011)
  - **Strong** and **Weak** ties are important, but for different things.
- The "diversity/bandwidth tradeoff".
  - More diversity, less bandwidth.
  - More bandwidth, less diversity.

Diversity/Bandwidth Tradeoff

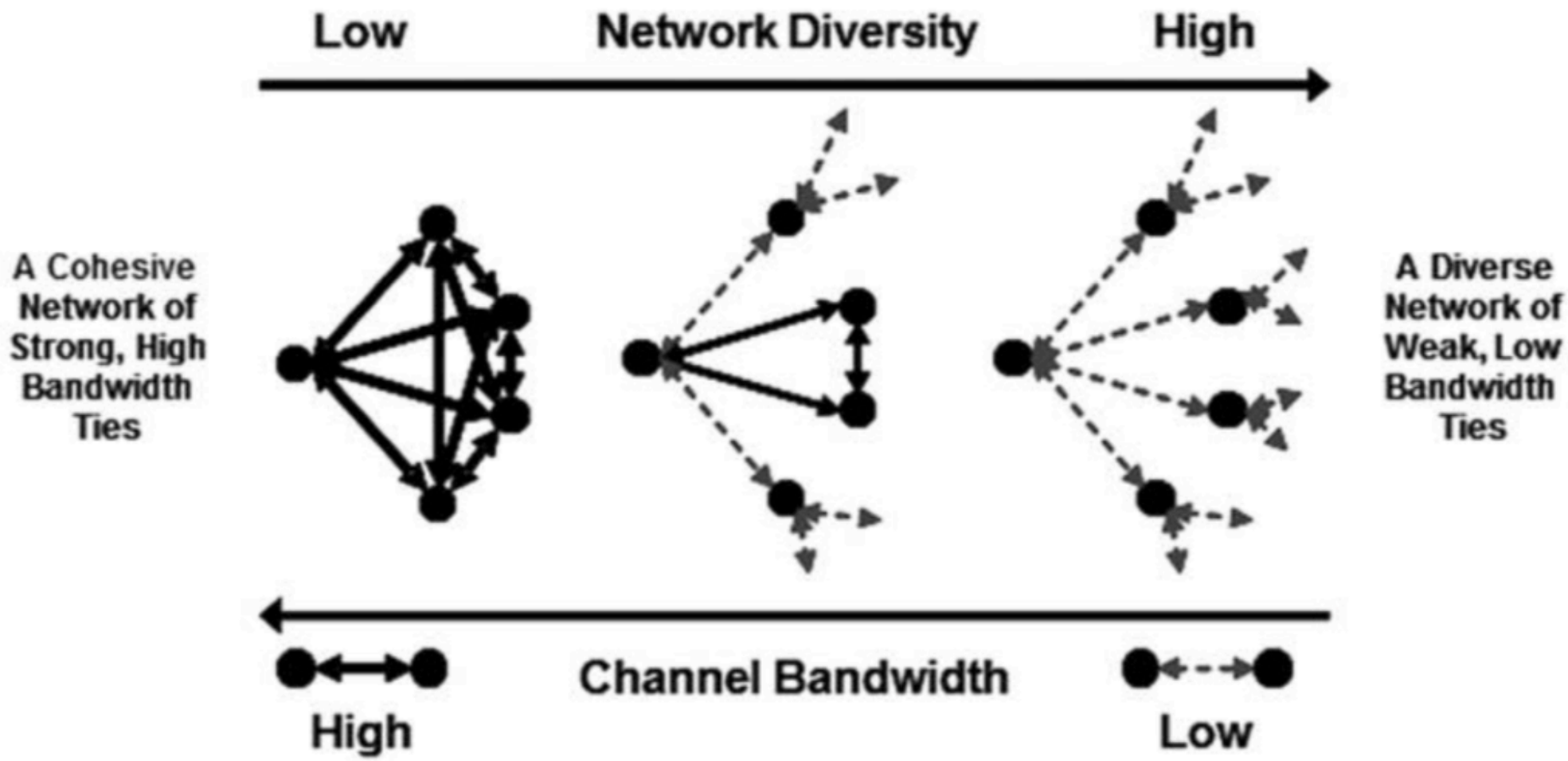


FIG. 1.—The diversity-bandwidth trade-off. As structural diversity increases, channel bandwidth decreases.

Illicit Networks

- Illicit Organizations face a similar problem
  - **Security/Efficiency Tradeoff**
    - Security-Maintain covert operations and avoid detection
    - Efficiency-Execute activities with efficiency to optimize output
      - The setting will shape network structure.

Learning Goals

- Understand an explanation of structural diversity in illicit networks.
- Revisit **degree** and **degree centralization**.
- Understand the differences between **error**/**attack** and **homogenous**/**inhomogeneous** in networks.
- Understand **security/efficiency tradeoff**.

Questions?

Break

Discussion

Network Theories and Theories of Networks*

	NETWORK THEORIES ("networks as *cause*")		THEORIES OF NETWORKS ("networks as *effects*")
	Explanatory Goal		*Explanatory Goal*
Explanatory Model	Social Capital/ Performance ("why are the benefits?")	Homogeneity ("why are nodes similar?")	Network Structure ("why is the network this way?")
Network Flow (ties as pipes)	<u>Capitalization</u> Definition: Acquisition to resources through ties and this influences human capital which contributes to performance. Examples: Access to unique information via bridging ties. Information control benefits of structural holes. Solving problems through access to diverse knowledge.	<u>Contagion</u> Definition: Nodes become similar through a process of "infection" where various "bits" are passed from one node to the other. Examples: Diffusion of innovations. Peer influence. Disease transmission.	Examples: Homophilous Selection ("why do people with the same attitudes cluster together? They sort into these groups")
Network Coordination (ties as bonds or "prisms")	<u>Cooperation</u> Definition: Networks provide benefits that can coordinate multiple nodes in order to bring all their resources to bear on a problem. Examples: Unionization. Collective efficacy in neighborhoods.	<u>Convergence</u> Definition: Nodes adapt to their environments, and as a result nodes with similar structural environments will demonstrate similarities. Examples: Administrative assistants have higher levels of communication in organizations.	Examples: Popularity ("why do some individuals receive more ties than others?")

*Adapted From Borgatti and Halgin (2011) and adams (2020).