Social Networks

POLI 100F

Course Plan

- 8/1 – Course introduction, student polls
- 8/3 – Network analysis: basics
- **8/8 – Network analysis: static networks**
- 8/10 – Network analysis: dynamic networks
- 8/15 – Social norms: diffusion
- 8/17 – Social norms: planned change
- 8/22 – Political networks
- 8/24 – Political networks
- 8/29 – Network theory
- 8/31 – Network theory, review

Evaluation

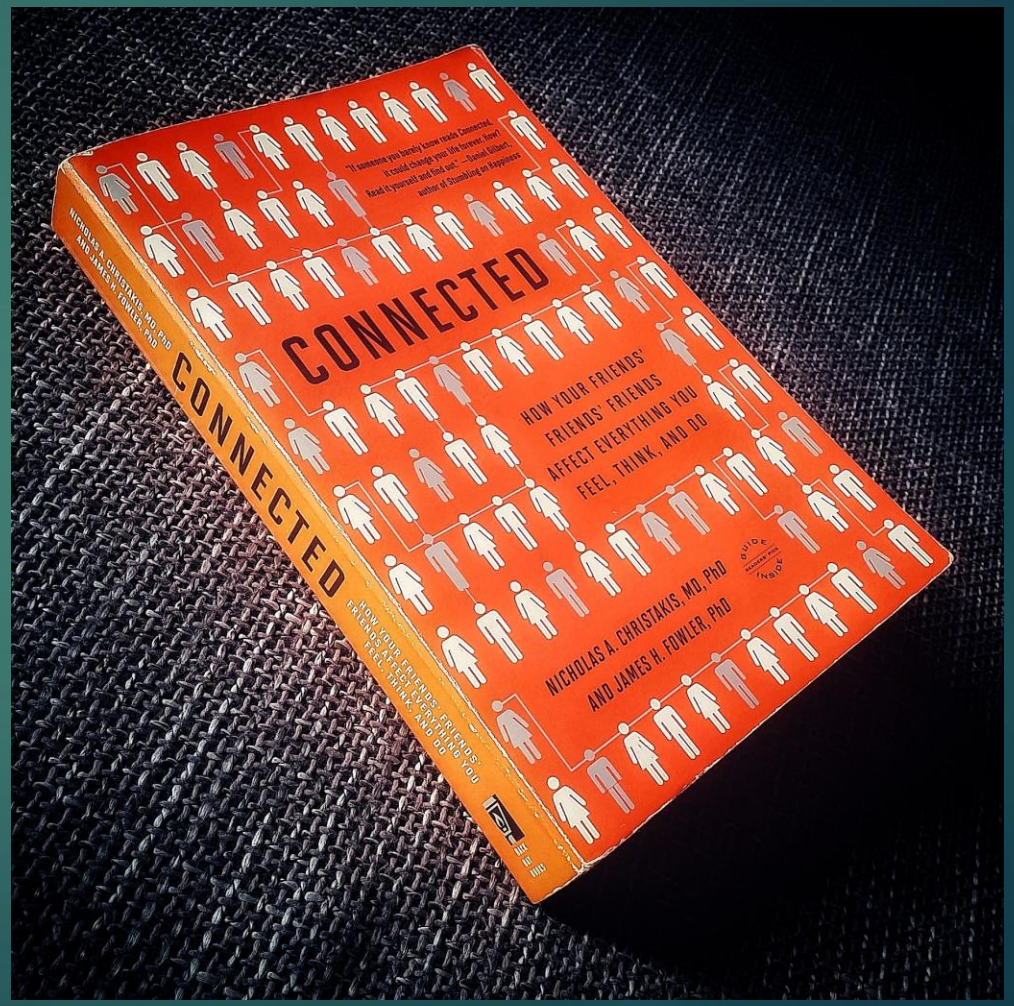
- Here's how your **final grade** will be calculated:
- Problem Set #1 - 30% [due August 12 @ 11:59pm]
- Problem Set #2 - 30% [due August 19 @ 11:59pm]
- Research proposal - 40% [due September 2; no final exam]

- **Attendance** at lecture is not required, but it is recommended because you'll have the opportunity to ask questions. All lectures will be **recorded** and posted on the corresponding Canvas page.

Required Text

- There's only one **required text** for the course, and it's in stock at the UCSD bookstore and available on Amazon for less than $20.

Nicholas A. Christakis and James H. Fowler. 2011. Connected: How Your Friends' Friends' Friends Affect Everything You Feel Think and Do. New York: Little Brown, ISBN: 9780316036139.



Office hours

- I'll be holding **office hours** on Wednesdays from 9-11am. You can sign up at the course Canvas page ("Start Here").
  - If that time's inconvenient or if all the slots are full, we can set something up by appointment. Message me on Canvas or email me at mdraper@ucsd.edu.

Social Network Analysis Terminology

- **Multi-mode Network** – Nodes represent more than one type of entity.
  - Contrast with uni-modal network: nodes only represent one type.
  - Example: some nodes may represent voters, others candidates or officeholders.
  - Also called affiliation or bipartite networks.
- **Node Attribute** – features or classifications of a node.
  - Example: whether a node has been exposed to a piece of information (or disease).

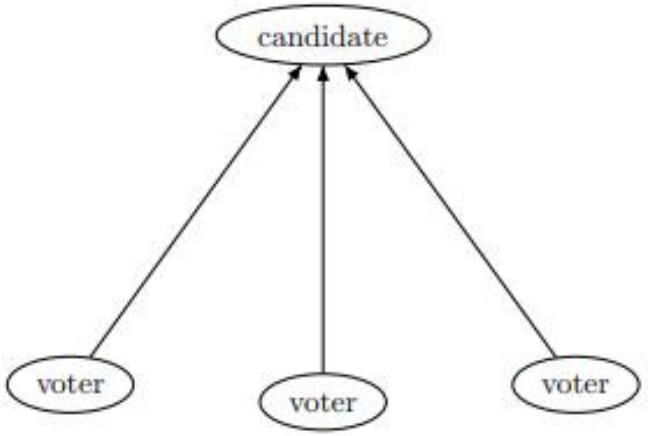
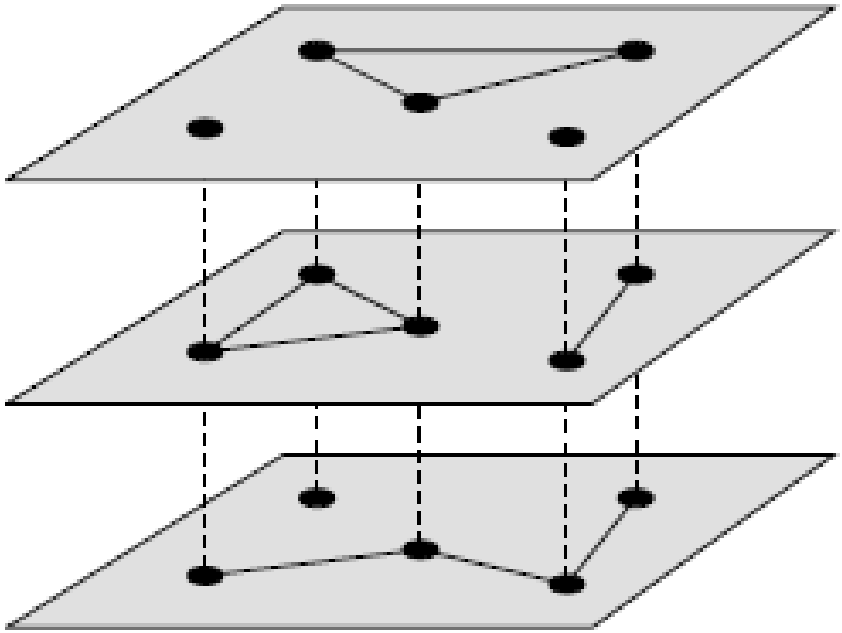


Figure 1: A social network of voters and a candidate.

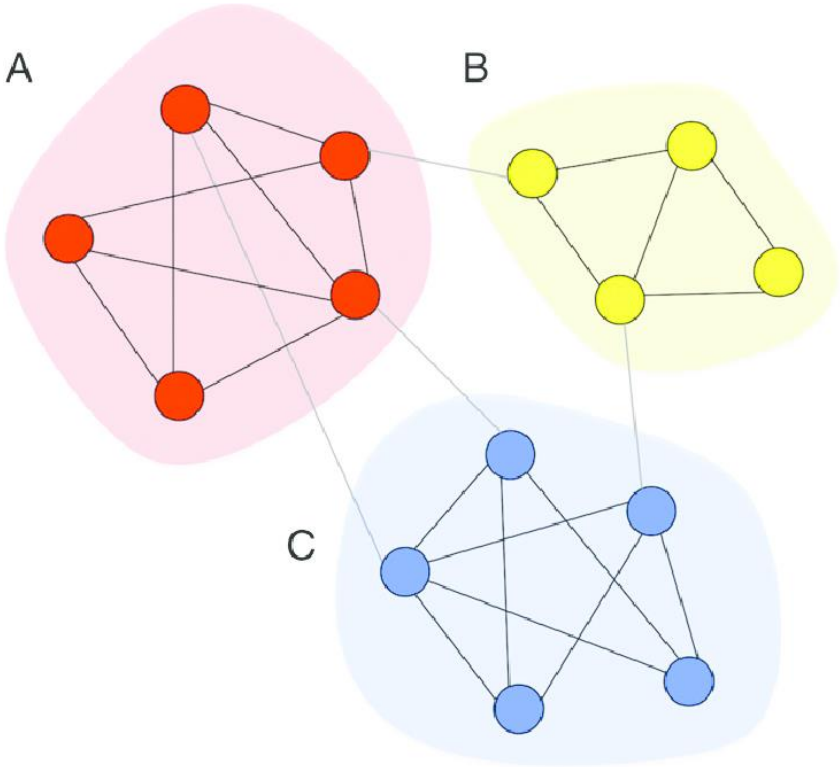
Social Network Analysis Terminology

- **Multiplex network** – more than one set of links; links represent different types of connection.
  - Example: different survey questions (who do you trust, who do others trust).
- Tie strength: the intensity of a link.
- Mark Granovetter - The Strength of Weak Ties (1973)
  - Weak ties are disproportionately likely to link to other parts of a network.



Social Network Analysis Terminology

- **Homophily** – the tendency of nodes to connect to others that are like them in some way. Also called "assortative mixing."
  - Occasionally reversed: heterophily, "disassortative mixing."
  - Theories of homophily: path dependency, similarity lowers costs, kin selection, many others.



Social Network Analysis Terminology

- **Contagion** – the tendency for behaviors, emotions or other conditions to spread through a network.
  - Behavioral contagion, emotional contagion.
  - Similar to but distinct from biological contagion.
- **Directionality** – links can be uni-directional or bi-directional.
  - Directed or undirected.
- Remember, where the nodes are located in 2d space is an arbitrary decision made by the analyst.
  - The same network can be visualized in different ways.

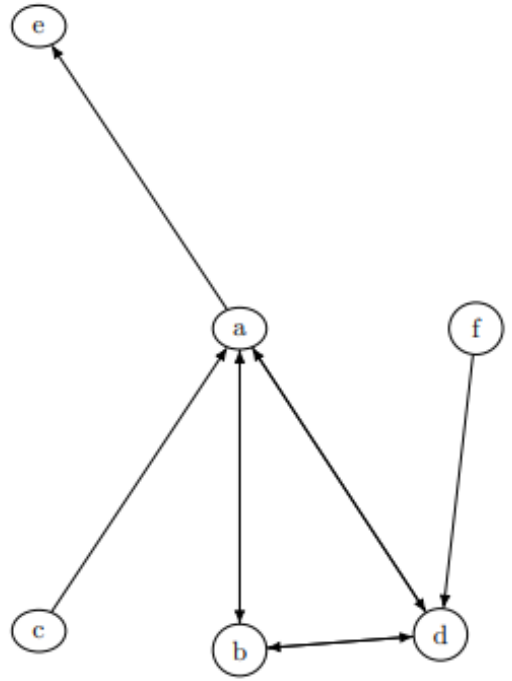
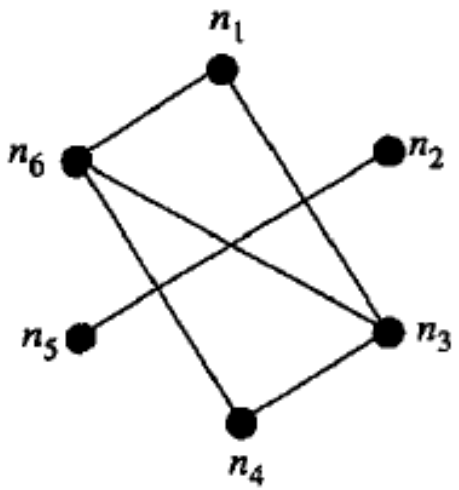
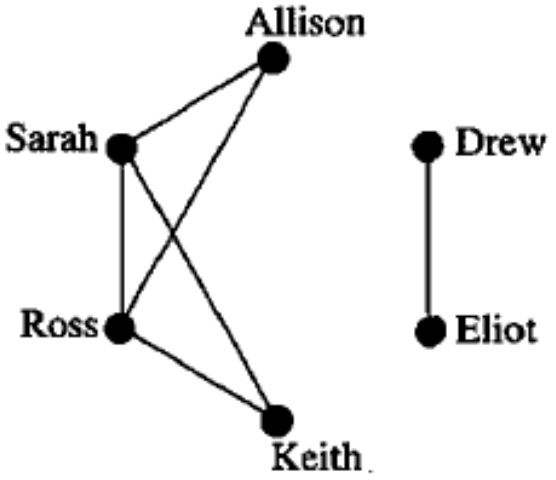


Figure 2: "Who do you go to for advice?"



$\mathcal{G}+$



$\mathcal{G}$

$\phi(n_1) = \text{Keith}$
$\phi(n_2) = \text{Eliot}$
$\phi(n_3) = \text{Sarah}$
$\phi(n_4) = \text{Allison}$
$\phi(n_5) = \text{Drew}$
$\phi(n_6) = \text{Ross}$

Fig. 4.13. Isomorphic graphs

Social Network Analysis Terminology

- **Adjacency Matrix**: a dataset representing all the links in the network. [represented by A]
- This is "the fundamental mathematical representation of a network."
- Symmetrical if the network is undirected, but not if it's directed.
- Unless we allow self-links, the main diagonal of the matrix (top left to bottom right) will contain all zeros.

	a	b	c	d	e	f
a	0	1	0	1	1	0
b	1	0	0	1	0	0
c	1	0	0	0	0	0
d	1	1	0	0	0	0
e	0	0	0	0	0	0
f	0	0	0	1	0	0

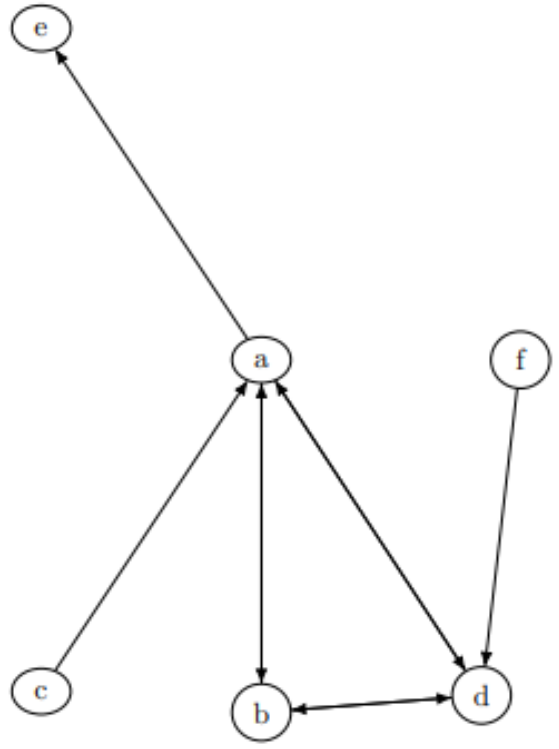


Figure 2: "Who do you go to for advice?"

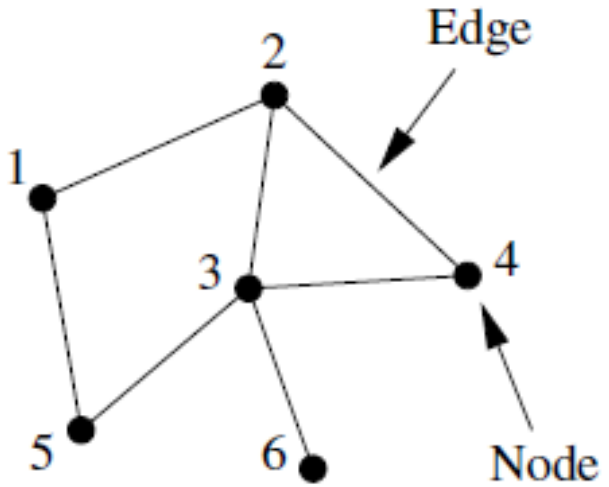
Social Network Analysis Terminology

The adjacency matrix **A** of the network is now defined to be the $n \times n$ matrix with elements A_{ij} such that

$$A_{ij} = \begin{cases} 1 & \text{if there is an edge between nodes } i \text{ and } j, \\ 0 & \text{otherwise.} \end{cases} \tag{6.1}$$

For example, the adjacency matrix of the network in Fig. 6.1a is

$$\mathbf{A} = \begin{pmatrix} 0 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{pmatrix}. \tag{6.2}$$



(a)

Social Network Analysis Terminology

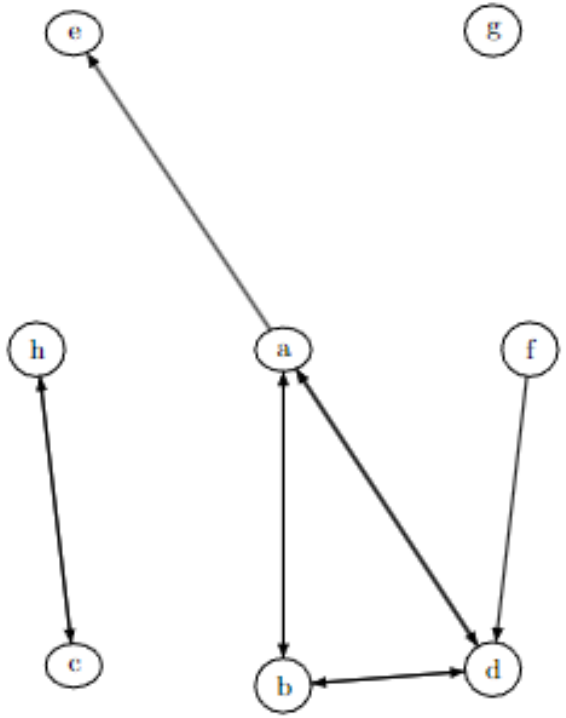


Figure 3: "Who do you go to for advice?"

- **Isolate**: a node with no links to any other nodes
- **Pendant**: a node with a single link to another node
- **Dyad**: two connected nodes
- **Triad**: three connected nodes
- **Neighbor:** a node one link away
- **Bridge:** a node located on the only path between two other nodes

Social Network Analysis Terminology

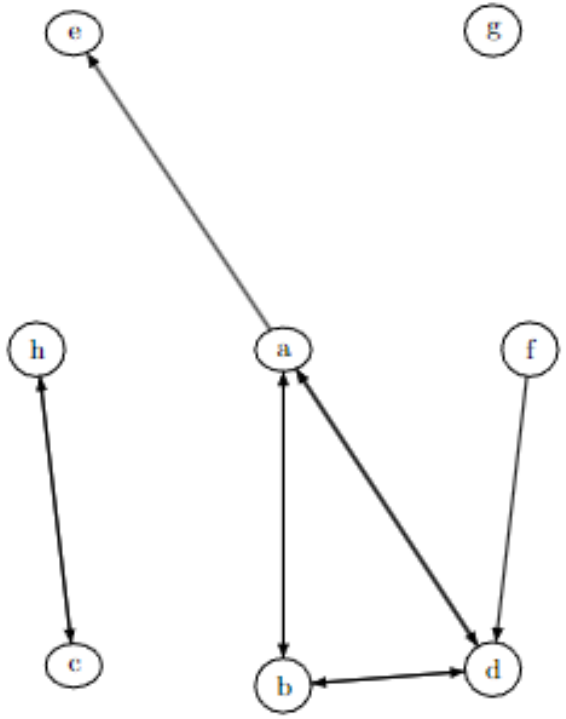
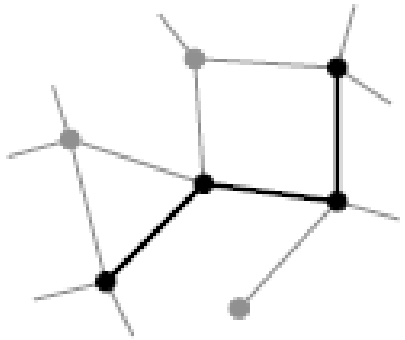


Figure 3: "Who do you go to for advice?"

- **Degree**: the number of connections a node has to other nodes. [represented by "k"]
  - In undirected networks, each link adds one degree.
  - In directed networks, degree is divisible into in-degree and out-degree.
    - **In-degree**: number of incoming links to a node
    - **Out-degree**: number of outgoing links to a node
  - So in this example, d has an in-degree of 3 and an out-degree of 2. Similarly, f has an in-degree of 0 and an out-degree of 1.

Social Network Analysis Terminology



A walk of length three in an undirected network.

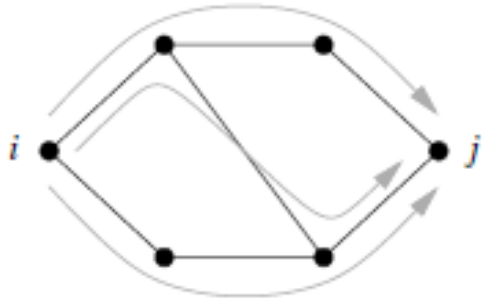
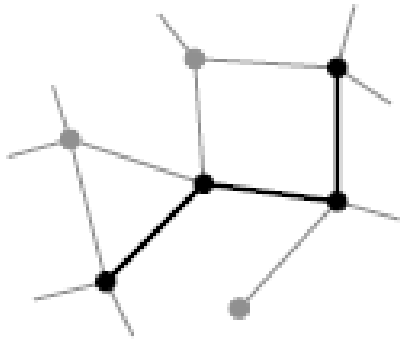


Figure 6.12: There are three shortest paths between nodes i and j in this network, each of length three.

- A **walk:** a route among the nodes passing along the links.
  - "…any sequence of nodes such that every consecutive pair of nodes in the sequence is connected by an edge."
- A **path**: a walk that never passes through the same node twice.
- A **geodesic**: the shortest path (fewest steps) between two nodes.
- The **diameter** of the network is the largest geodesic in the network.

Social Network Analysis Terminology



A walk of length three in an undirected network.

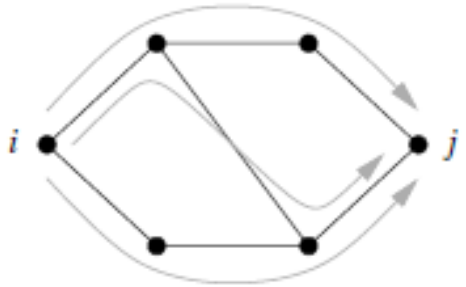


Figure 6.12: There are three shortest paths between nodes *i* and *j* in this network, each of length three.

- A **cycle**: a walk that ends on the same node where it began.
  - "A cycle in a directed network is a closed loop of edges with the arrows on each of the edges pointing the same way around the loop."
- The **average path length** of a network is the average length of all the geodesics.
  - Six degrees of separation (Milgram): average path length of 5.5.

Social Network Analysis Terminology

- Identifying **communities** in a network:
- A **component** is "a subset of the nodes of a network such that there exists at least one path from each member of that subset to each other member, and such that no other node in the network can be added to the subset while preserving this property.

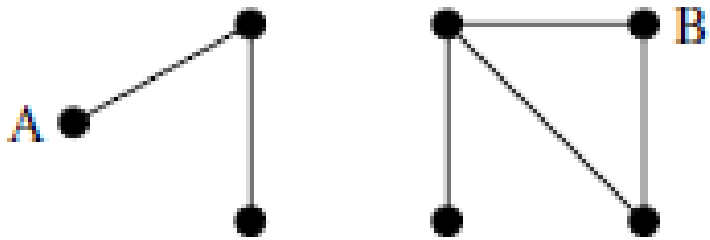
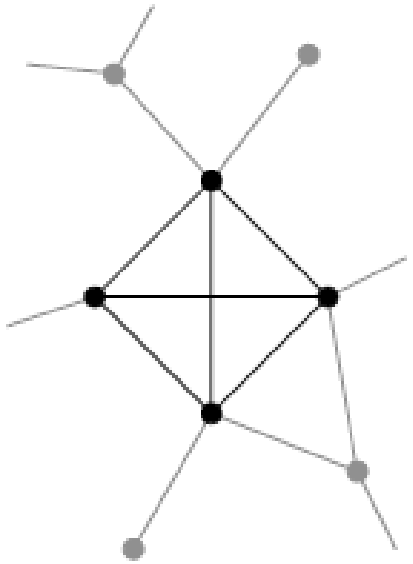


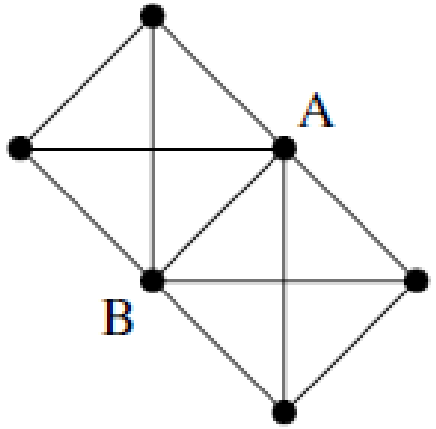
Figure 6.13: A network with two components. There is no path between nodes like A and B that lie in different components.

Social Network Analysis Terminology

- Identifying **communities** in a network:
- A **clique** is a community where every node is connected to every other node. Cliques can overlap.



A clique of four nodes within a network.



Two overlapping cliques. Nodes A and B in this network both belong to two cliques of four nodes.

Social Network Analysis Terminology

- A **weakly-connected** component has a (non-directed) path between every dyad.
- A **strongly-connected** component has a directed path from each node to every other node.

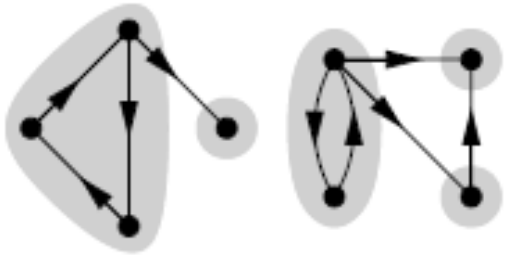
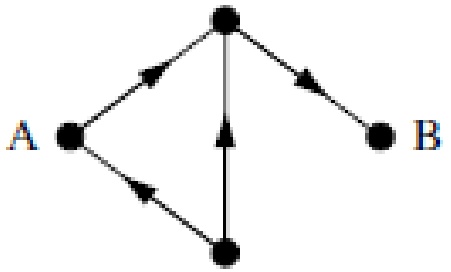


Figure 6.14: Components in a directed network. This network has two weakly connected components of four nodes each, and five strongly connected components (shaded).



There is a directed path from A to B in this network, but none from B to A.

Social Network Analysis Terminology

- In mathematics a relation “” is said to be **transitive** if a b and b c together imply a c.
- In social network theory, nodes are connected by edges. Networks aren’t perfectly transitive, because a<->b and b<->c doesn’t mean c->a or a->c.
- However, in social networks, if we know that a->b and b->c, there’s a greater likelihood that c->a.
- “the friend of my friend is more likely than average to be my friend.”
- This is what we mean by **network transitivity**.

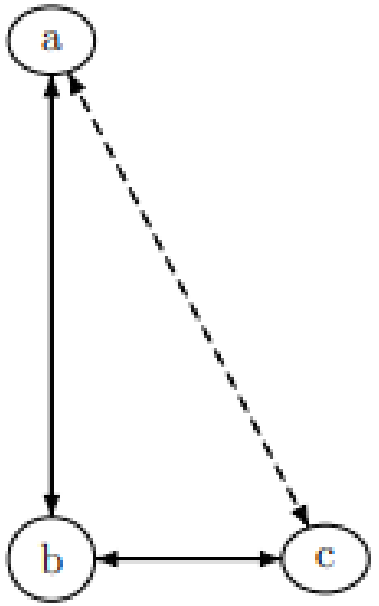
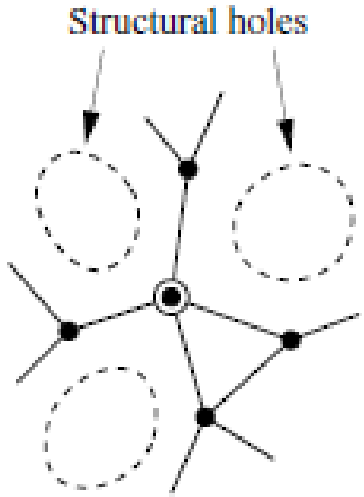


Figure 4: A triad

Social Network Analysis Terminology

- While it is common in social networks, for the neighbors of a node to be connected among themselves, it often happens that these expected connections between neighbors are missing. The missing links are called **structural holes**. These can be desirable (ex: epidemic prevention).
- A node whose role in the network is enhanced by structural holes is known as a **broker**, like the central node here:



When the neighbors of a node are not connected to one another we say the network contains "structural holes."

Social Network Analysis Terminology

- We can quantify the level of transitivity in the network as the fraction of paths of length two that are closed, or (more commonly) as the number of connected triads divided by the number of triads. This is called the **clustering coefficient** [C].
- No perfectly transitive components (or networks) exist that are not also cliques. Another way to put this is that all cliques are completely transitive.
- Think of it as "the mean probability that two people with a common friend are themselves friends."

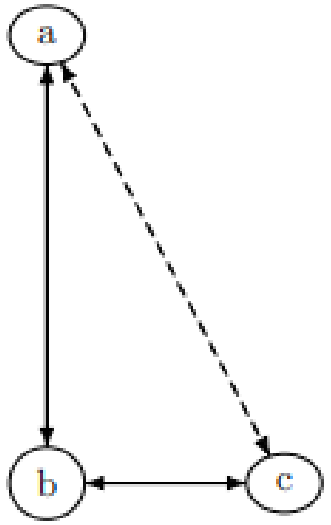
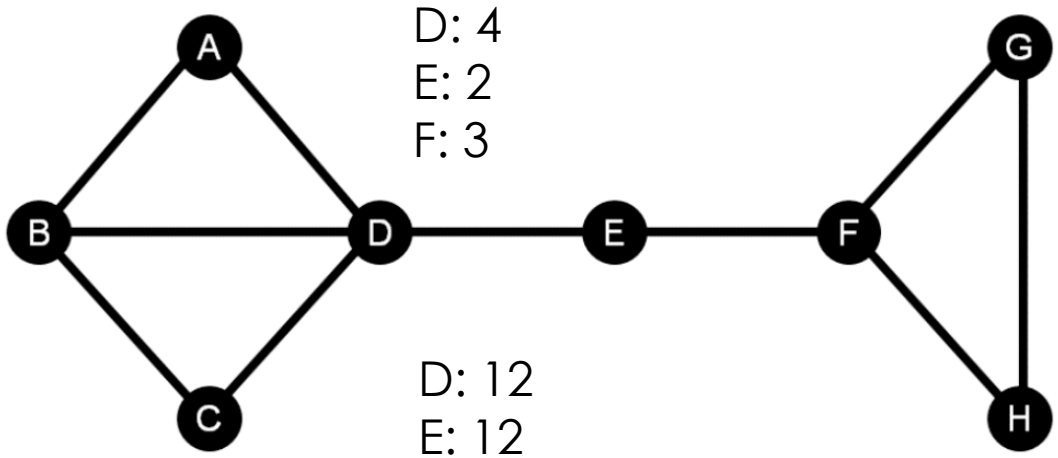


Figure 4: A triad

$$C = \frac{(\text{number of triangles}) \times 3}{(\text{number of connected triples})}.$$

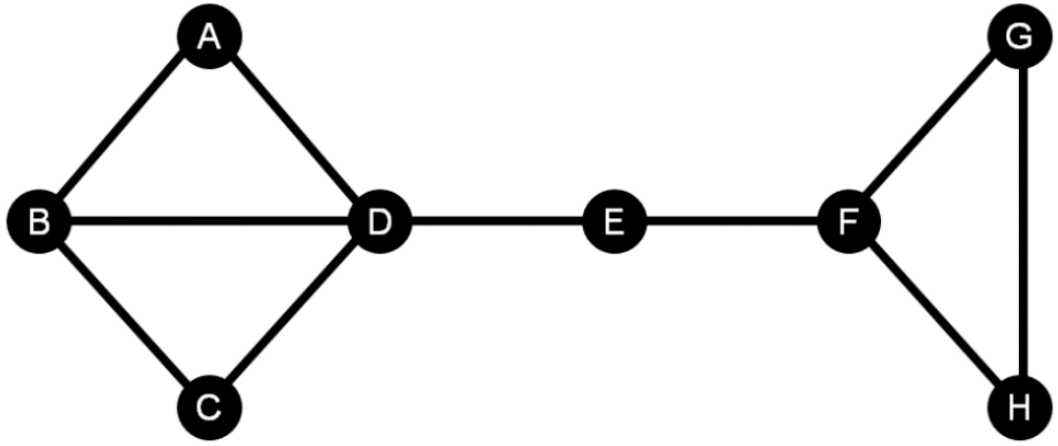
Social Network Analysis Terminology

- There are several different types of **network centrality**: which nodes are most central to the network?
- **Degree Centrality**: which node has the most connections?
  - Can be divided into in-degree centrality and out-degree centrality.
- **Closeness Centrality:** the node that is closest to all the other nodes (the fewest steps in a walk).



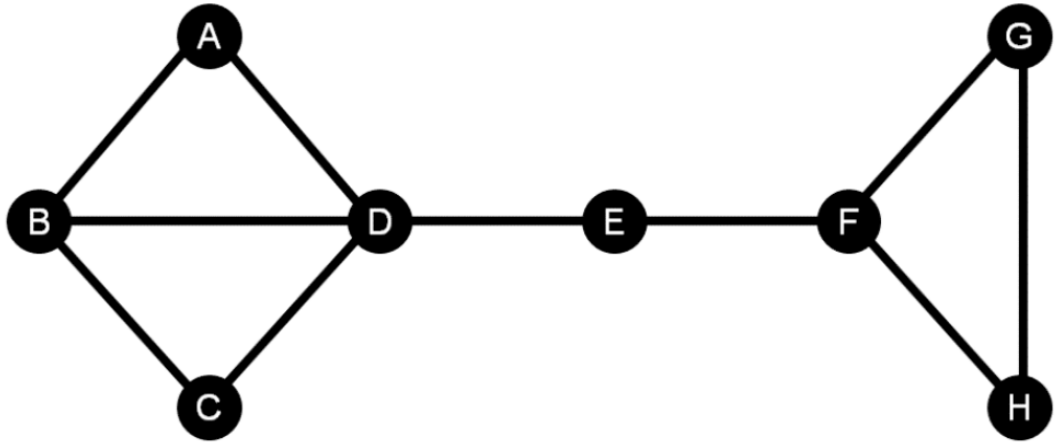
Social Network Analysis Terminology

- There are several different types of **network centrality**: which nodes are most central to the network?
- **Betweenness Centrality:** which node is on the most paths connecting other nodes?
  - Ex: A has to go through D to get to E, F, G and H (4). Same for B and C (4+4). E has to go through D to get to A, B and C (3), and same for F, G and H (3+3+3). So the betweenness centrality of D is 4+4+4+3+3+3+3=24.



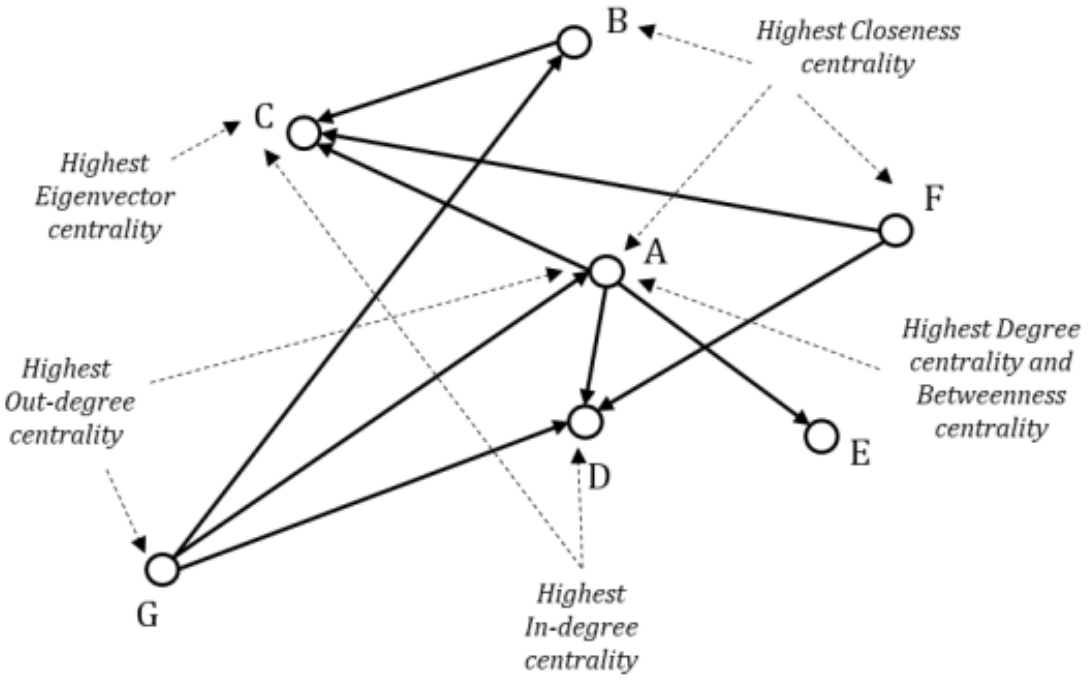
Social Network Analysis Terminology

- There are several different types of **network centrality**: which nodes are most central to the network?
- **Eigenvector Centrality:** the average centrality score of a node's direct links. A node's eigenvector centrality score is proportional to the centrality score of linked nodes.
  - Ex: D's direct links are A, B, C and E. A is linked to one other node (B), B is linked to two other nodes (A and C), C is linked to one other node (B), and E is linked to one other node (F), giving D an eigenvector centrality of 5/4.



Social Network Analysis Terminology

- An overview of centrality measures:
- **Degree Centrality**: how many connections does the node have?
  - Can be divided into **in-degree** centrality and **out-degree** centrality.
- **Closeness Centrality:** how close is the node to all the other nodes?
- **Betweenness Centrality:** how many paths go through this node?
- **Eigenvector Centrality:** how many links do the nodes linked to this link have?



Literature: Sociology

- Mark Granovetter: The Strength of Weak Ties (1973)
- "A fundamental weakness of current sociological theory is that it does not relate micro-level interactions to macro-level patterns in any convincing way…the analysis of processes in interpersonal networks provides the most fruitful micro-macro bridge."
- **Tie strength**: "the strength of a tie is a (probably linear) combination of the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie."

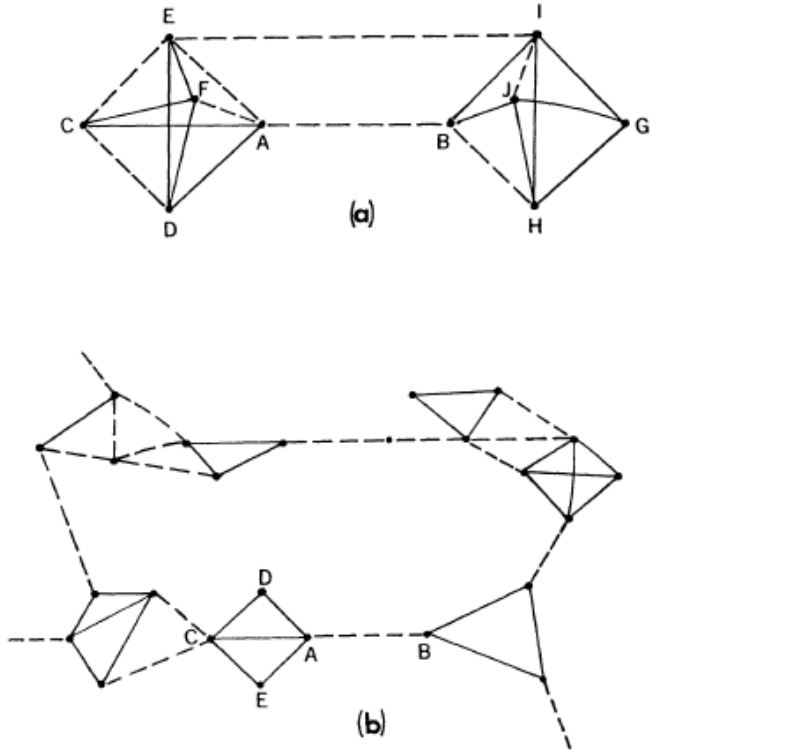


FIG. 2.—Local bridges. *a*, Degree 3; *b*, Degree 13. ——— = strong tie; — — — = weak tie.

Literature: Sociology

- Mark Granovetter: The Strength of Weak Ties (1973)
- Hypothesis: "the stronger the tie between A and B, the larger the proportion of individuals in [the set] to whom they will both be tied, that is, connected by a weak or strong tie."
- "…the triad which is most unlikely to occur, under the hypothesis stated above, is that in which A and B are strongly linked, A has a strong tie to some friend C, but the tie between C and B is absent."

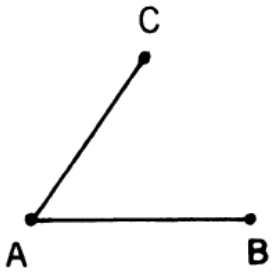


FIG. 1.—Forbidden triad

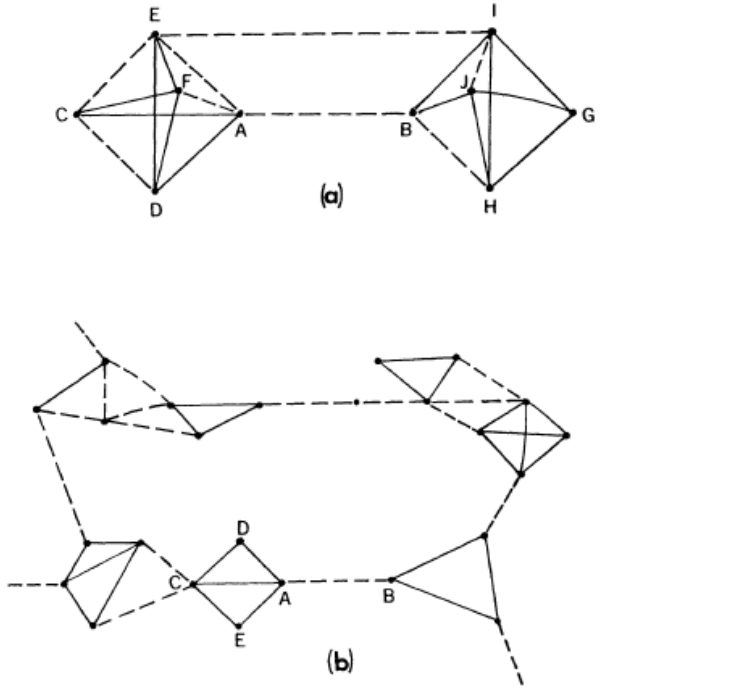


FIG. 2.—Local bridges. *a*, Degree 3; *b*, Degree 13. ——— = strong tie; — — — = weak tie.

Literature: Sociology

- Mark Granovetter: The Strength of Weak Ties (1973)
- “The significance of this triad's absence can be shown by using the concept of a "**bridge**"; this is a line in a network which provides the only path between two points.”
- “if the stipulated triad is absent, it follows that, except under unlikely conditions, no strong tie is a bridge…all bridges are weak ties.”
- “In large networks it probably happens only rarely, in practice, that a specific tie provides the only path between two points. The bridging function may nevertheless be served locally…[a] **local bridge**…”

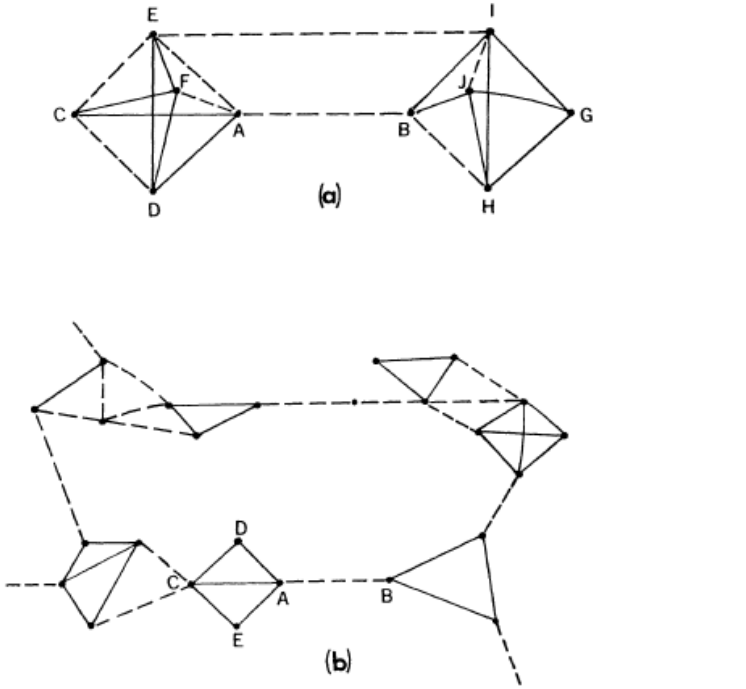


FIG. 2.—Local bridges. *a*, Degree 3; *b*, Degree 13. ——— = strong tie; — — — = weak tie.

Literature: Sociology

- Mark Granovetter: The Strength of Weak Ties (1973)
- “I will refer to a tie as a "local bridge of degree n" if n represents the shortest path between its two points (other than itself), and n > 2. In figure 2a, A-B is a local bridge of degree 3, in 2b, of degree 13.”
- “The significance of weak ties, then, would be that those which are local bridges create more, and shorter, paths”
- “The contention here is that removal of the average weak tie would do more "damage" to transmission probabilities than would that of the average strong one.”

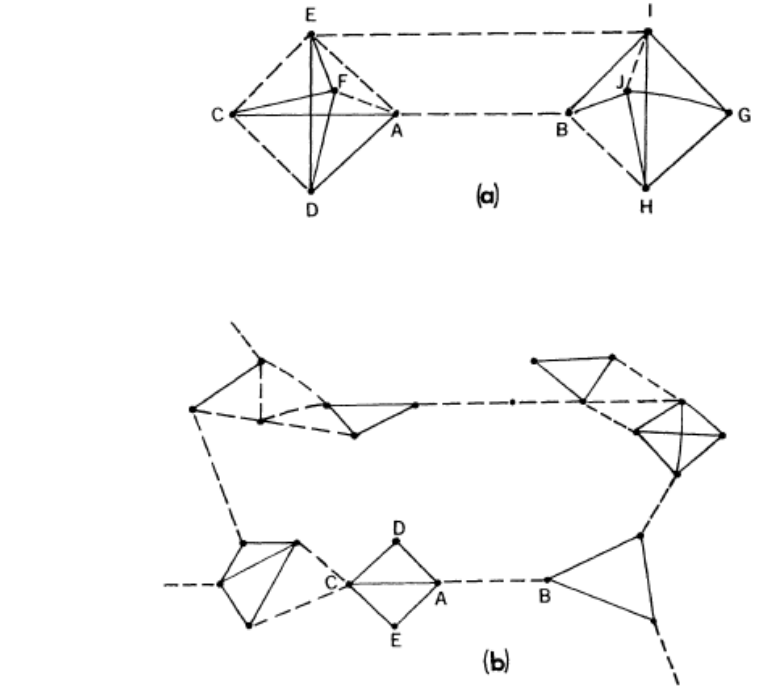


FIG. 2.—Local bridges. *a*, Degree 3; *b*, Degree 13. ——— = strong tie; — — — = weak tie.

Literature: Sociology

- Mark Granovetter: The Strength of Weak Ties (1973)
- “Intuitively speaking, this means that whatever is to be diffused can reach a larger number of people, and traverse greater social distance (i.e., path length),’ when passed through weak ties rather than strong.”
- “the rumor moving through strong ties is much more likely to be limited to a few cliques than that going via weak ones; bridges will not be crossed.”
- Experimental evidence: “The smallest total number of people were reached through the networks generated by first and second choices-presumably the strongest ties-and the largest number through seventh and eighth choices.”

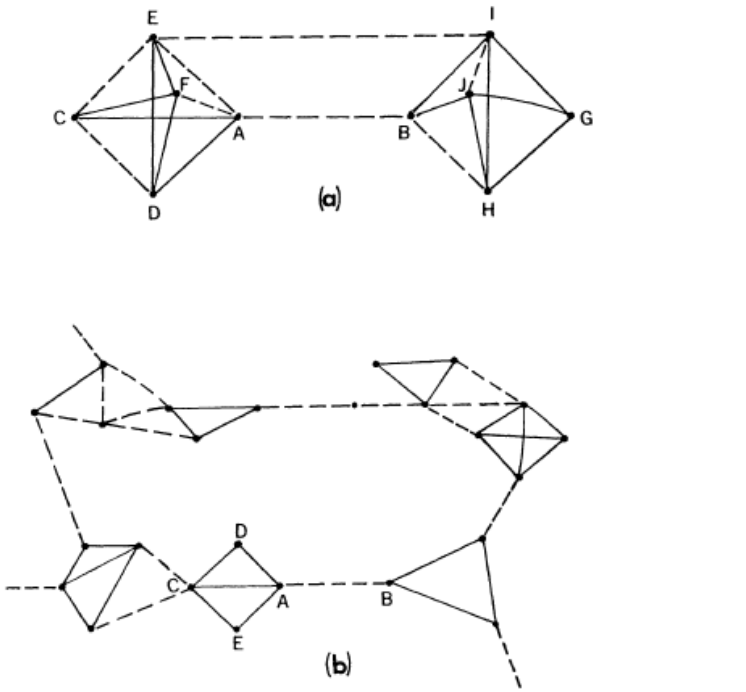


FIG. 2.—Local bridges. *a*, Degree 3; *b*, Degree 13. ——— = strong tie; — — — = weak tie.

Literature: Sociology

- Mark Granovetter: The Strength of Weak Ties (1973)
- "The fewer indirect contacts one has the more encapsulated he will be in terms of knowledge of the world beyond his own friendship circle; thus, bridging weak ties (and the consequent indirect contacts) are important in both ways."
- "It is suggested…that for a community to have many weak ties which bridge, there must be several distinct ways or contexts in which people may form them."
- "the more local bridges (per person?) in a community and the greater their degree, the more cohesive the community and the more capable of acting in concert."

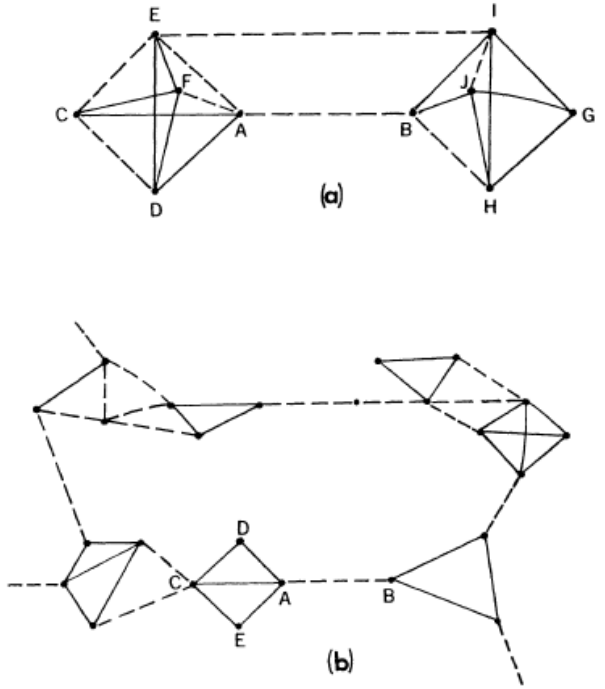
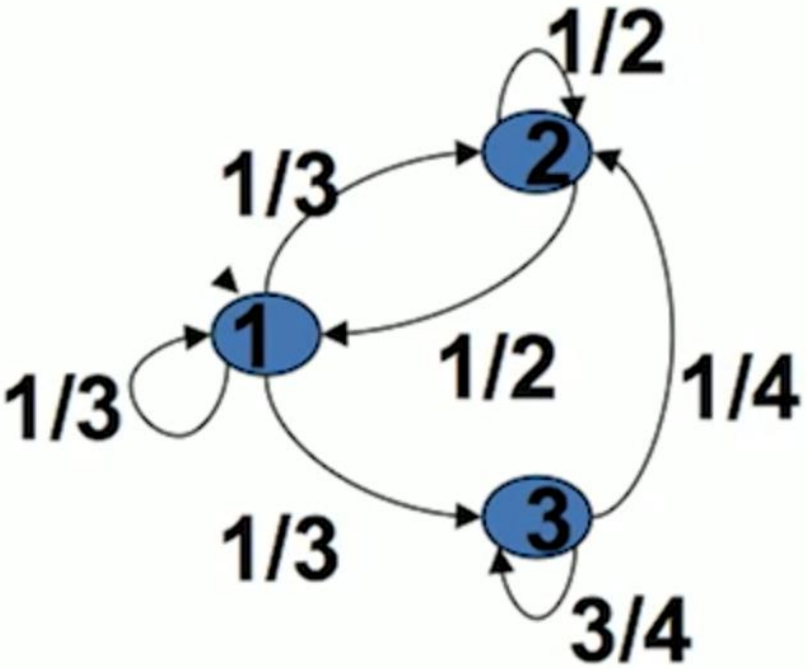


FIG. 2.—Local bridges. *a*, Degree 3; *b*, Degree 13. ——— = strong tie; — — — = weak tie.

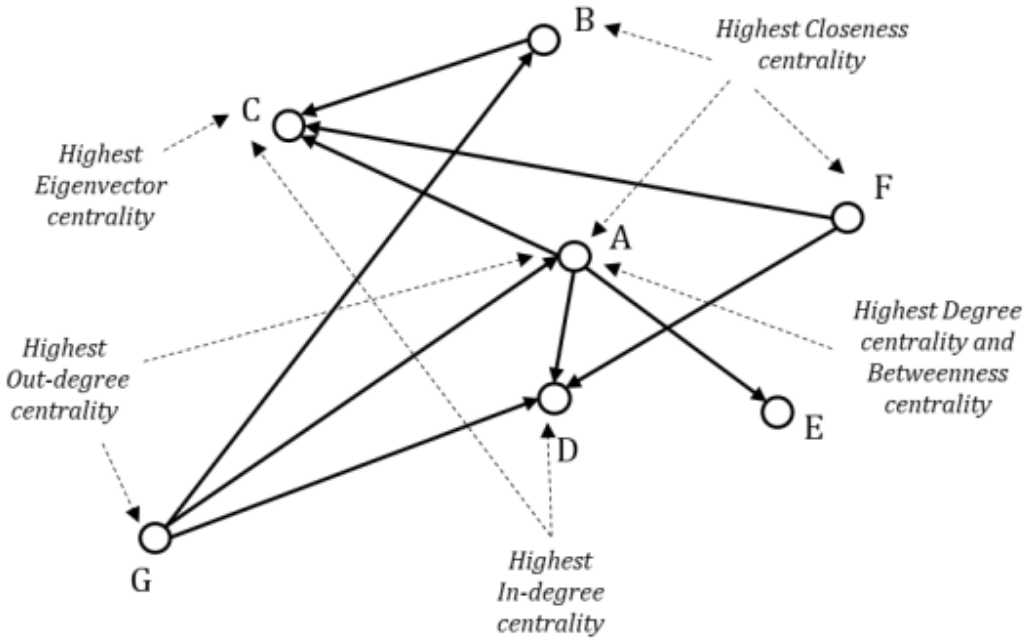
Social Network Analysis Concepts

- Tie strength: we've already seen that we can distinguish between strong and weak ties. We can also **weight** the tie strength using a continuous measure. This can (but need not) sum to 1 depending on the application.
  - Ex. How much time do you spend together each day? [need not sum to 1]
  - Ex. Who influences your decision? [sums to 1]



Social Network Analysis Concepts

- "A **graph** is a way of specifying relationships among a collection of items. A graph consists of a set of objects, called **nodes**, with certain pairs of these objects connected by links called **edges**."
- "We say that two nodes are neighbors if they are connected by an edge."
- "[W]e define a **directed graph** to consist of a set of nodes, as before, together with a set of **directed edges**; each directed edge is a link from one node to another, with the direction being important…When we want to emphasize that a graph is not directed, we can refer to it as an **undirected graph.**"



Social Network Analysis Concepts

- "[A] **path** is…a sequence of nodes with the property that each consecutive pair in the sequence is connected by an edge… a **cycle** is a path with at least three edges, in which the first and last nodes are the same, but otherwise all nodes are distinct."
- "[W]e say that a graph is connected if for every pair of nodes, there is a path between them."
  - "there is no a priori reason to expect graphs in other settings to be connected"

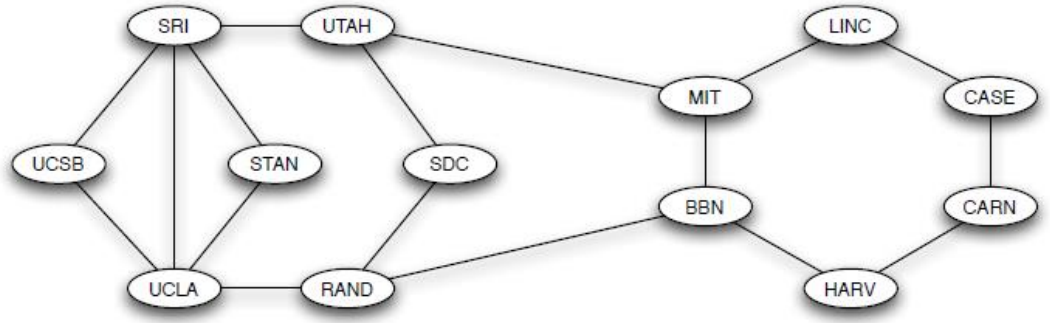


Figure 2.3: An alternate drawing of the 13-node Internet graph from December 1970.

"[E]very edge in the 1970 Arpanet belongs to a cycle, and this was by design"

Social Network Analysis Concepts

- "[A] **connected component** of a graph (often shortened just to the term "component") is a subset of the nodes such that:
  - (i) every node in the subset has a path to every other; and
  - (ii) the subset is not part of some larger set with the property that every node can reach every other.
- "…large, complex networks often have what is called a giant component, a deliberately informal term for a connected component that contains a significant fraction of all the nodes….when a network contains a giant component, it almost always contains only one."

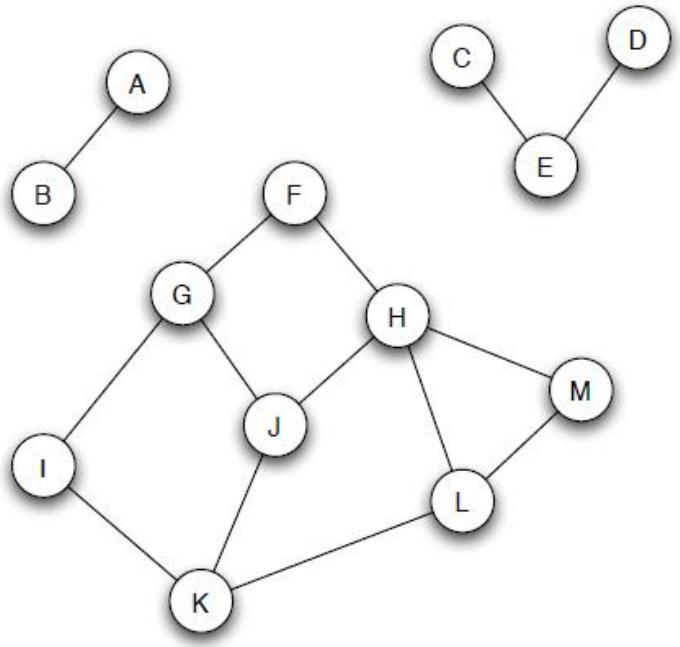


Figure 2.5: A graph with three connected components.

Social Network Analysis Concepts

- "…large, complex networks often have what is called a **giant component**, a deliberately informal term for a connected component that contains a significant fraction of all the nodes….when a network contains a giant component, it almost always contains only one."
- "All it would take is a single edge from someone in the first of these components to someone in the second, and the two giant components would merge into a single component…hence two co-existing giant components are something one almost never sees in real networks."

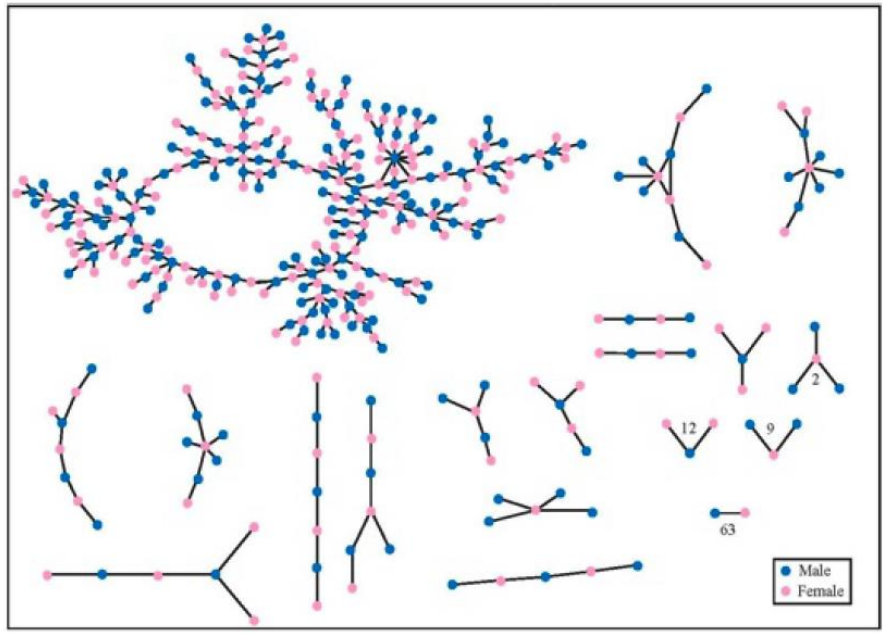


Figure 2.7: A network in which the nodes are students in a large American high school, and an edge joins two who had a romantic relationship at some point during the 18-month period in which the study was conducted [49].

Social Network Analysis Concepts

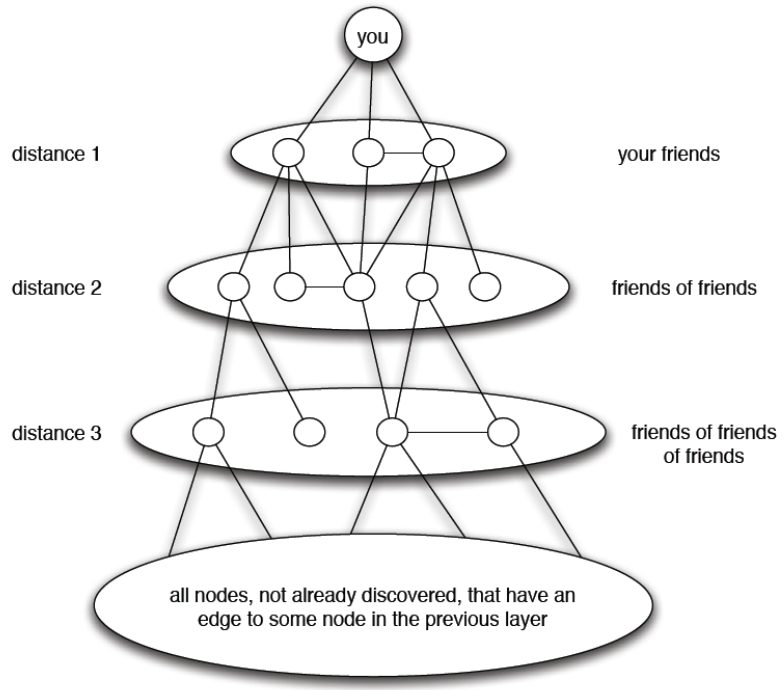
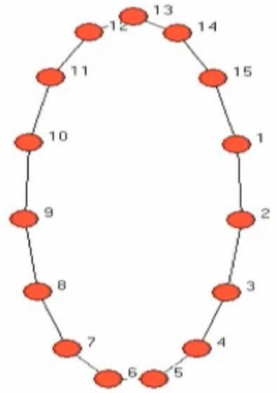


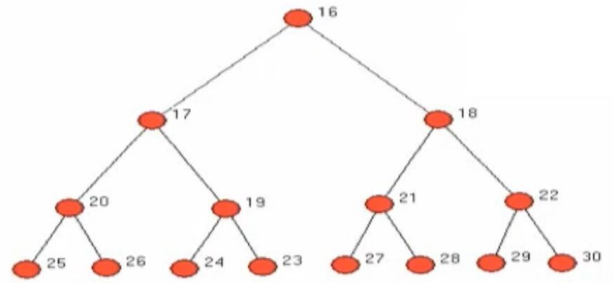
Figure 2.8: Breadth-first search discovers distances to nodes one "layer" at a time; each layer is built of nodes that have an edge to at least one node in the previous layer.

- Breadth-first search: categorize nodes by their path distance from some starting node.

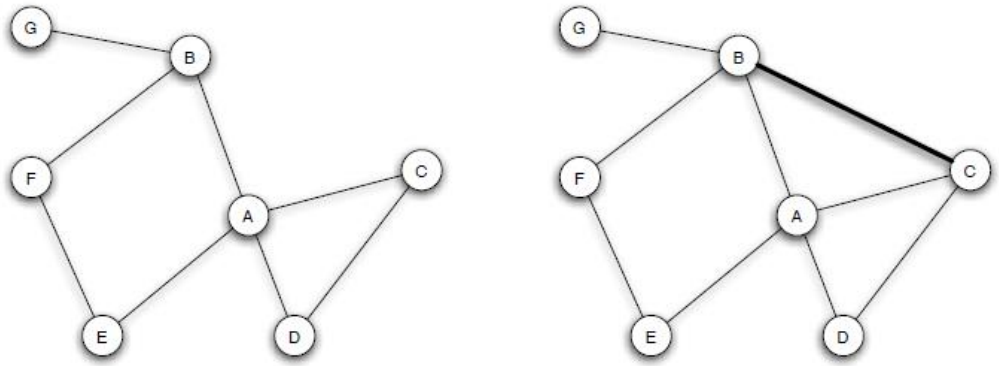
Social Network Analysis Concepts

- Recall that a network's **diameter** is the largest geodesic in the network (or if the network is unconnected, the largest geodesic of the largest component).
- Consider these two networks. Can we calculate their diameter?
- In the ring network, the diameter will scale linearly (n/2). In the tree network, the diameter scales logarithmically ($2\log_2(n+1)$).





Social Network Analysis Concepts

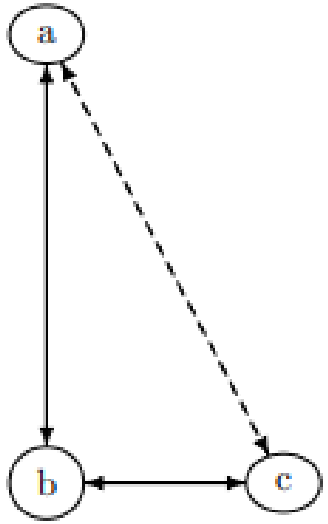


(a) *Before B-C edge forms.* (b) *After B-C edge forms.*

Figure 3.1: The formation of the edge between B and C illustrates the effects of triadic closure, since they have a common neighbor A.

- **Triadic closure**: if nodes B and C have a friend A in common, then the formation of an edge between B and C produces a situation in which all three nodes A, B, and C have edges connecting each other..."
- Recall Granovetter's hypothesis that the so-called forbidden triad was rare. We can interpret this as a claim that triads will tend to close over time [preview of dynamic networks].

Social Network Analysis Concepts



$$C = \frac{(\text{number of triangles}) \times 3}{(\text{number of connected triples})}.$$

- Recall the **clustering coefficient** [C].
- "The clustering coefficient of a node A is defined as the probability that two randomly selected friends of A are friends with each other. In other words, it is the fraction of pairs of A's friends that are connected to each other by edges."
- "…the clustering coefficient of a node ranges from 0 (when none of the node's friends are friends with each other) to 1 (when all of the node's friends are friends with each other), and the more strongly triadic closure is operating in the neighborhood of the node, the higher the clustering coefficient will tend to be.

Social Network Analysis Concepts

- "We say that an edge joining two nodes A and B in a graph is a **local bridge** if its endpoints A and B have no friends in common…[in other words] if deleting the edge would increase the distance between A and B to a value strictly more than two."
- "[T]he **span** of a local bridge is the distance its endpoints would be from each other if the edge were deleted."

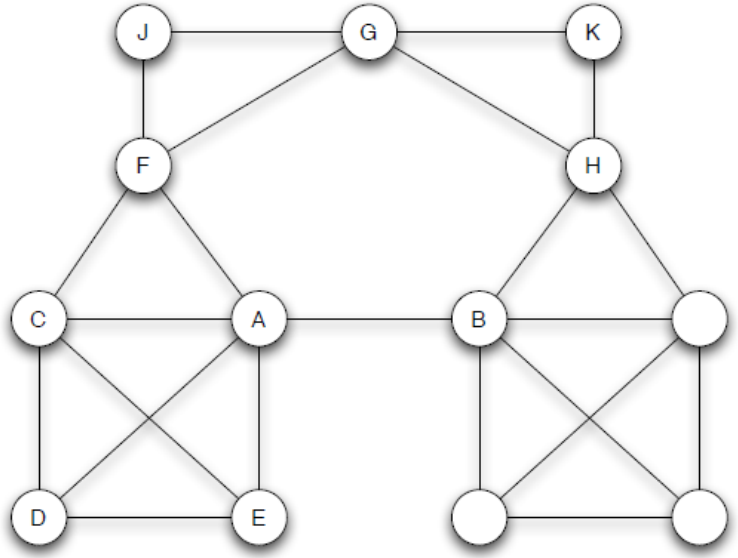


Figure 3.4: The A-B edge is a local bridge of span 4, since the removal of this edge would increase the distance between A and B to 4.

Social Network Analysis Concepts

- "Notice that the definition of a local bridge already makes an implicit connection with triadic closure, in that the two notions form **conceptual opposites**: an edge is a local bridge precisely when it does not form a side of any triangle in the graph."
- "…a local bridge between nodes A and B tends to be a weak tie because if it weren't, triadic closure would tend to produce short-cuts to A and B that would eliminate its role as a local bridge."

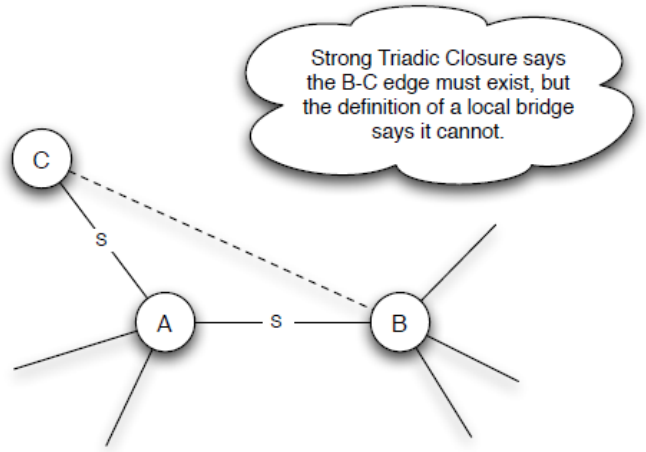
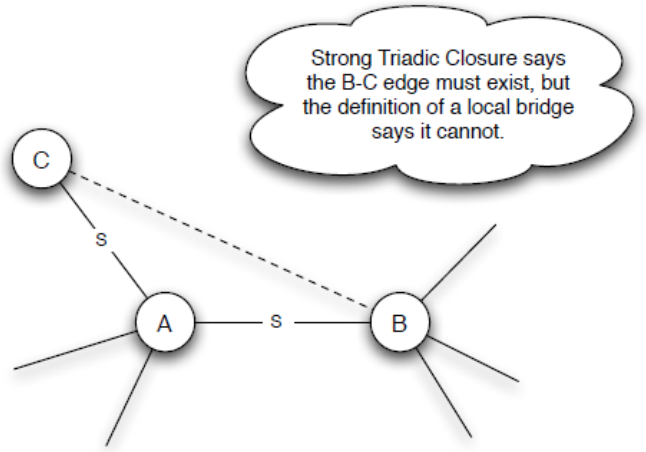


Figure 3.6: If a node satifies Strong Triadic Closure and is involved in at least two strong ties, then any local bridge it is involved in must be a weak tie. The figure illustrates the reason why: if the A-B edge is a strong tie, then there must also be an edge between B and C, meaning that the A-B edge cannot be a local bridge.

Social Network Analysis Concepts

- Global patterns:
  - Path length
  - Degree distribution
- Local patterns:
  - Homophily
  - Clustering
  - Transitivity
- Positional patterns:
  - Centrality
  - Influence



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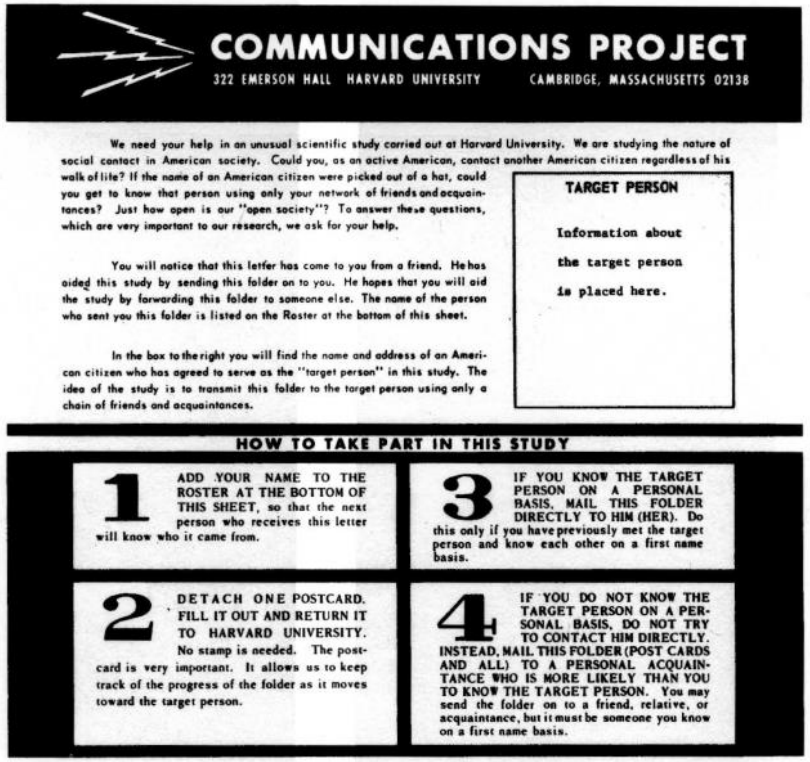
Literature: Social Psychology

- “Starting with any two people in the world, what is the probability that they will know one another?" A somewhat more complex formulation, however, takes account of the fact that while persons X and Z may not know each other directly, they may share a mutual acquaintance...”
- “Therefore, another question one may ask is: given any two people in the world, person X and person Z, how many intermediate acquaintance links are needed before X and Z are connected?”



COMMUNICATIONS PROJECT

322 EMERSON HALL HARVARD UNIVERSITY CAMBRIDGE, MASSACHUSETTS 02138

We need your help in an unusual scientific study carried out at Harvard University. We are studying the nature of social contact in American society. Could you, as an active American, contact another American citizen regardless of his walk of life? If the name of an American citizen were picked out of a hat, could you get to know that person using only your network of friends and acquaintances? Just how open is our "open society"? To answer these questions, which are very important to our research, we ask for your help.

You will notice that this letter has come to you from a friend. He has aided this study by sending this folder on to you. He hopes that you will aid the study by forwarding this folder to someone else. The name of the person who sent you this folder is listed on the Roster at the bottom of this sheet.

In the box to the right you will find the name and address of an American citizen who has agreed to serve as the "target person" in this study. The idea of the study is to transmit this folder to the target person using only a chain of friends and acquaintances.

TARGET PERSON

Information about the target person is placed here.

HOW TO TAKE PART IN THIS STUDY

1 ADD YOUR NAME TO THE ROSTER AT THE BOTTOM OF THIS SHEET, so that the next person who receives this letter will know who it came from.

2 DETACH ONE POSTCARD. FILL IT OUT AND RETURN IT TO HARVARD UNIVERSITY. No stamp is needed. The postcard is very important. It allows us to keep track of the progress of the folder as it moves toward the target person.

3 IF YOU KNOW THE TARGET PERSON ON A PERSONAL BASIS, MAIL THIS FOLDER DIRECTLY TO HIM (HER). Do this only if you have previously met the target person and know each other on a first name basis.

4 IF YOU DO NOT KNOW THE TARGET PERSON ON A PERSONAL BASIS, DO NOT TRY TO CONTACT HIM DIRECTLY. INSTEAD, MAIL THIS FOLDER (POST CARDS AND ALL) TO A PERSONAL ACQUAINTANCE WHO IS MORE LIKELY THAN YOU TO KNOW THE TARGET PERSON. You may send the folder on to a friend, relative, or acquaintance, but it must be someone you know on a first name basis.

Literature: Social Psychology

- "There are two general philosophical views on the small world problem. [One view] sees the world in terms of isolated clusters of acquaintances. [Another] view sees acquaintances in terms of an infinitely intersecting arrangement that permits movement from any social grouping to another through a series of connecting links."
- "One way of restating the small world problem…is this: given any two of these points chosen at random from this universe, through how many intermediate points would we pass before they could be connected by the shortest possible path?"

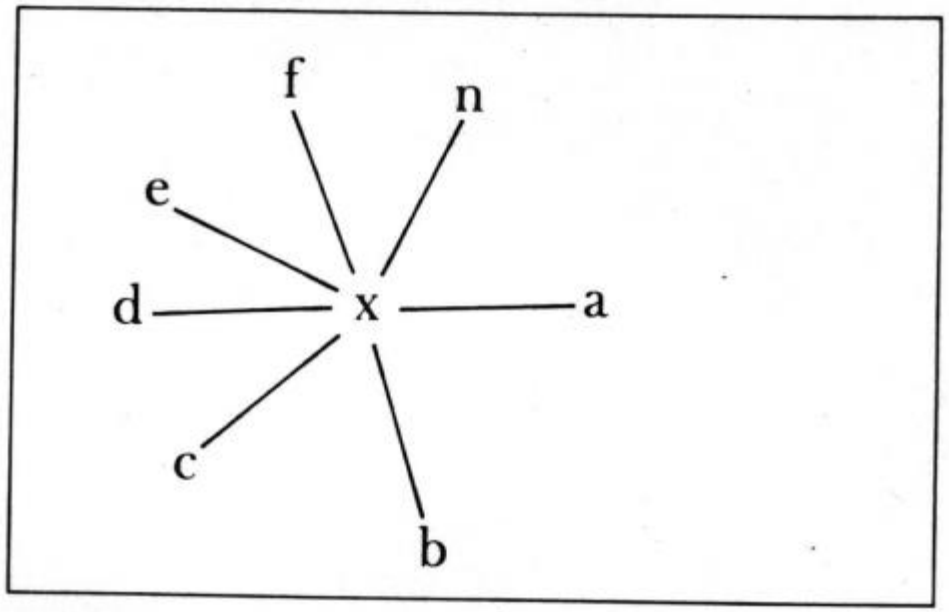
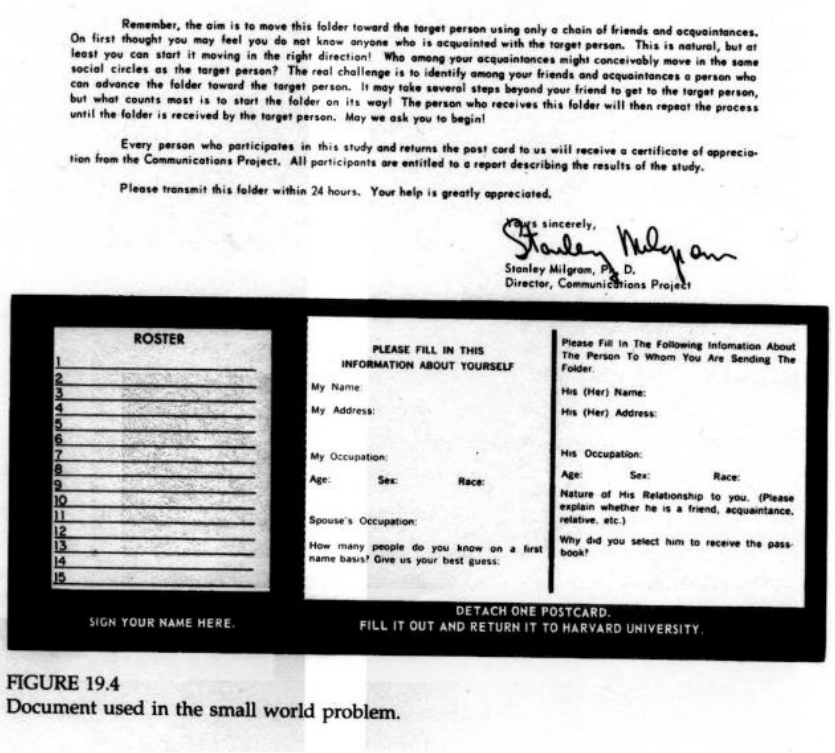


FIGURE 19.1
Acquaintances of X, *a*, . . . , *n*.

Literature: Social Psychology



Remember, the aim is to move this folder toward the target person using only a chain of friends and acquaintances. On first thought you may feel you do not know anyone who is acquainted with the target person. This is natural, but at least you can start it moving in the right direction! Who among your acquaintances might conceivably move in the same social circles as the target person? The real challenge is to identify among your friends and acquaintances a person who can advance the folder toward the target person. It may take several steps beyond your friend to get to the target person, but what counts most is to start the folder on its way! The person who receives this folder will then repeat the process until the folder is received by the target person. May we ask you to begin!

Every person who participates in this study and returns the post card to us will receive a certificate of appreciation from the Communications Project. All participants are entitled to a report describing the results of the study.

Please transmit this folder within 24 hours. Your help is greatly appreciated.

Yours sincerely,

Stanley Milgram, Ph. D.
Director, Communications Project

ROSTER

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

SIGN YOUR NAME HERE.

PLEASE FILL IN THIS INFORMATION ABOUT YOURSELF

My Name:

My Address:

My Occupation:

Age: Sex: Race:

Spouse's Occupation:

How many people do you know on a first name basis? Give us your best guess:

Please Fill In The Following Infomation About The Person To Whom You Are Sending The Folder.

His (Her) Name:

His (Her) Address:

His Occupation:

Age: Sex: Race:

Nature of His Relationship to you. (Please explain whether he is a friend, acquaintance, relative, etc.)

Why did you select him to receive the passbook?

DETACH ONE POSTCARD.
FILL IT OUT AND RETURN IT TO HARVARD UNIVERSITY.

FIGURE 19.4
Document used in the small world problem.

- "The general procedure was to obtain a sample of men and women from varied walks of life. Each of these persons was given the name and address of "Target Person"…Each of the participants was asked to move a message towards the target person using only a chain of friends and acquaintances."
- "Each person could transmit the message to one friend or acquaintance who would be more likely to know the target person than he was. The friend would repeat the process until the message reached the target person. Messages may only move to persons who know each other on a first-name basis."

Literature: Social Psychology

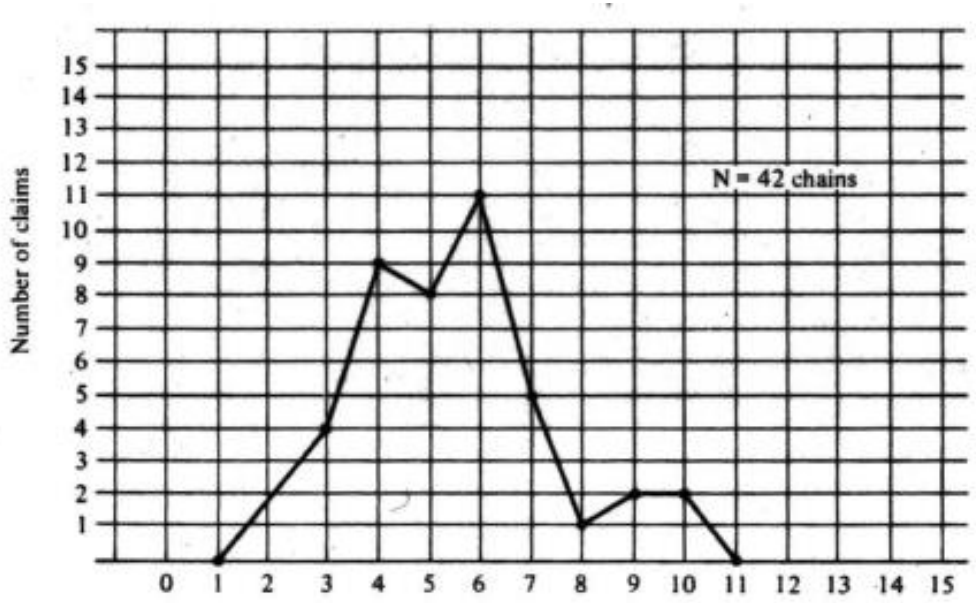


FIGURE 19.5
Number of intermediaries needed to reach target person. Each chain started in Nebraska and reached a target person in Massachusetts.

"The question that plagued us most in undertaking this study was simply: Would the procedure work? Would any chains started in Kansas actually reach our target person in Massachusetts? The answer came fairly quickly. **Within a few days** after initiating chains in Kansas, one of the documents was returned to the target person, the wife of a Divinity School student. The document had started with a wheat farmer in Kansas. He passed it on to an Episcopal minister in his home town, who sent it to a minister who taught in Cambridge, who gave it to the target person. Altogether the number of intermediate links between starting person and target person amounted to two!"

Literature: Social Psychology

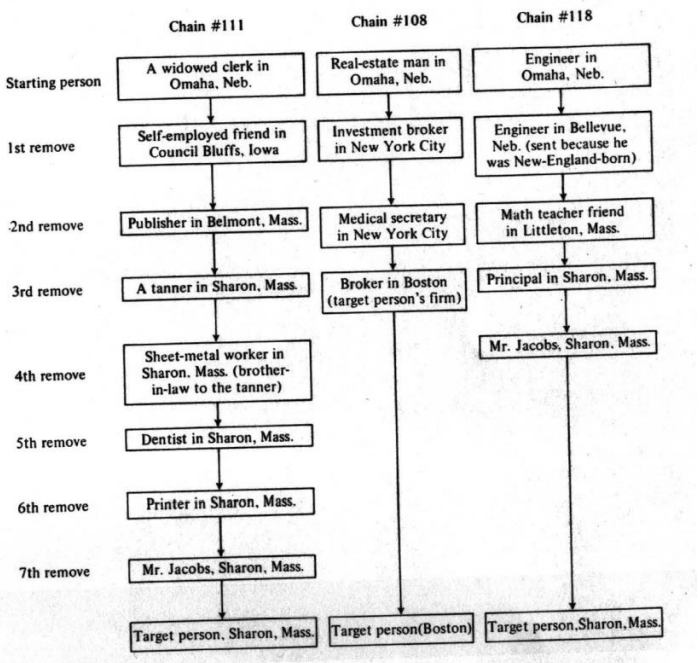


FIGURE 19.6
Typical chains in the Nebraska study.

- **Homophily**: The researchers found a "very pronounced tendency in our Kansas study for female participants to send the folder on to females, while males tended to send the folder on to other males. For a total of 145 subjects involved in the study...subjects were three times as likely to send the folder on to someone of the same sex as someone of the opposite sex."
- **Weak Ties:** "Subjects also indicated on the tracer cards whether they were sending the folder on to friends, relatives, or acquaintances. In this same series, 123 cards were sent to friends and acquaintances, while only 22 were sent to relatives."

Literature: Social Psychology

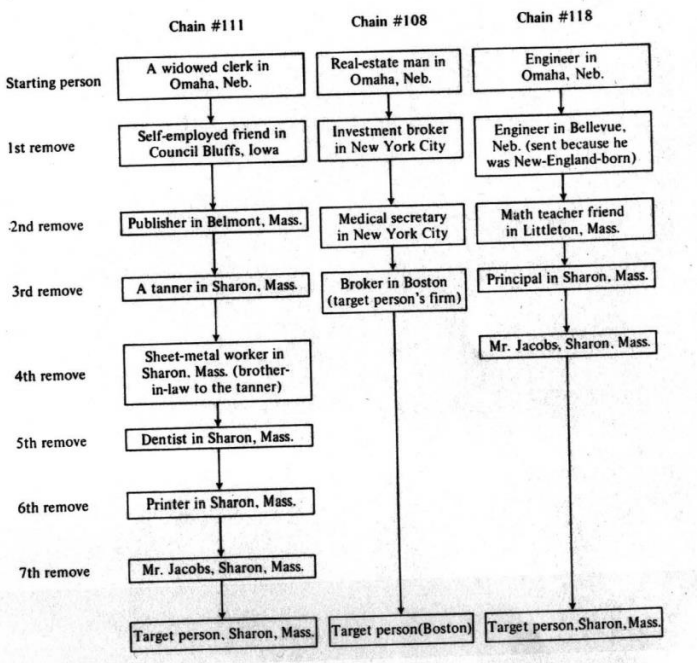


FIGURE 19.6
Typical chains in the Nebraska study.

- **Theorem**: "There is an interesting theorem based on the model of the small world. It states that if persons from two different populations cannot make contact, that no one within the entire population in which each is embedded can make contact with any person in the other population. Said differently, given person a embedded in population A (which consists of his circle of acquaintances), and person b embedded in population B, if a cannot make contact with b, then:
- 1. No other individual in A can make contact with b.
- 2. No other individual in A can make contact with any other individual in B.
- 3. In other words, the two subpopulations are completely isolated from each other."

Literature: Social Psychology

- **What if we vary the starting population?**

TABLE 2

Lengths of Completed Chains

Population	Frequency Distribution: Number of Intermediaries												
	0	1	2	3	4	5	6	7	8	9	10	11	Total
Nebraska Random	0	0	0	1	4	3	6	2	0	1	1	0	18
Nebraska Stock	0	0	0	3	6	4	6	2	1	1	1	0	24
Boston Random	0	2	3	4	4	1	4	2	1	0	1	0	22
All	0	2	3	8	14	8	16	6	2	2	3	0	64

Means	
Starting Population	Mean Chain Length
Nebraska Random	5.7
Nebraska Stockholders	5.4
All Nebraska	5.5
Boston Random	4.4
All	5.2

Literature: Social Psychology

- "Let us consider in detail the pattern of convergence crystallizing around the target person of our second target person, a stock broker living in Sharon, Massachusetts, and working in Boston. A total of 62 chains reached him, 24 of these at his place of residence in a small town outside of Boston. Within Sharon, fully sixteen were given to the target person by Mr. Jacobs, a clothing merchant in town. He served as the principal point of mediation between the target person and the larger world, a fact that came as a considerable surprise, and even something of a shock for the target person."

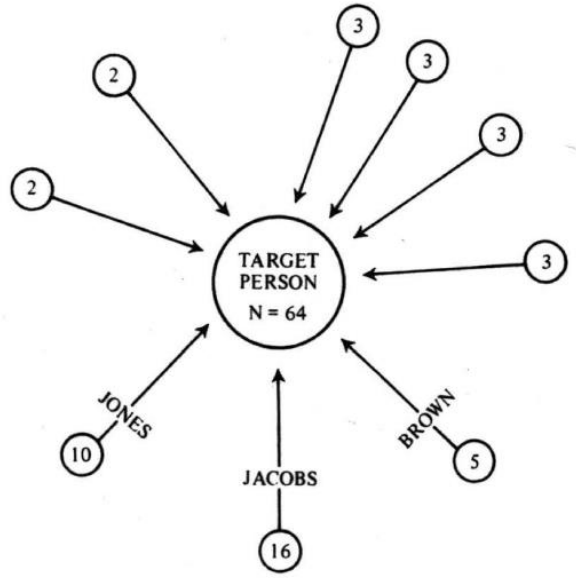


FIGURE 19.7
Convergence through common channels (includes 42 chains that started in Nebraska and 22 that started in the Boston area).

Literature: Social Psychology

- "At his place of work in a Boston brokerage house, ten of the chains passed through Mr. Jones, and five through Mr. Brown, business colleagues of the target person. Indeed, 48 percent of the chains to reach the target person were moved on to him by three persons: Jacobs, Jones, and Brown. Between Jacobs and Jones there is an interesting division of labor. Jacobs mediates the chains advancing to the target person by virtue of his residence. Jones performs a similar function in the occupational domain, and moves 10 chains enmeshed in the investment-brokerage network to the target person (Fig. 19.7)."

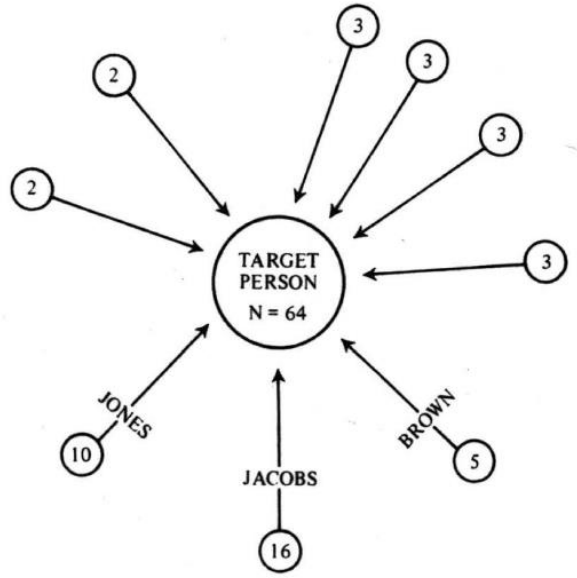


FIGURE 19.7
Convergence through common channels (includes 42 chains that started in Nebraska and 22 that started in the Boston area).

Literature: Social Psychology

- "As stated previously, many people were surprised to learn that only 5.5 intermediaries will, on the average, suffice to link randomly chosen individuals, no matter where each lives in the United States. We ought to try to explain the discrepancy between intuition and fact...The first point to remember is that although we deal drrectly with only 5.5 intermediaries, behind each of them stands a much larger group of from 500 to 2500 persons. That is, each participant selects from an acquaintance pool of 500 to 2500 persons the individual he thinks is in the best position to advance the chain, and we deal only with the end product of a radical screening procedure. Second, there is an element of geometric progression implicit in the search procedure, and there is nothing more alien to mathematically untutored intuition than this form of thinking."

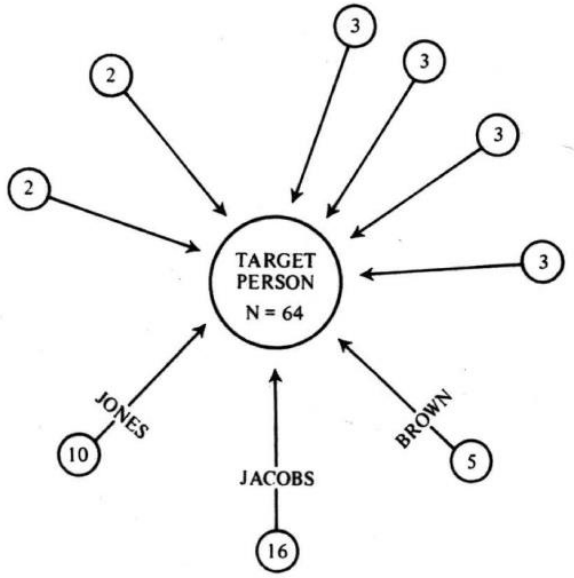
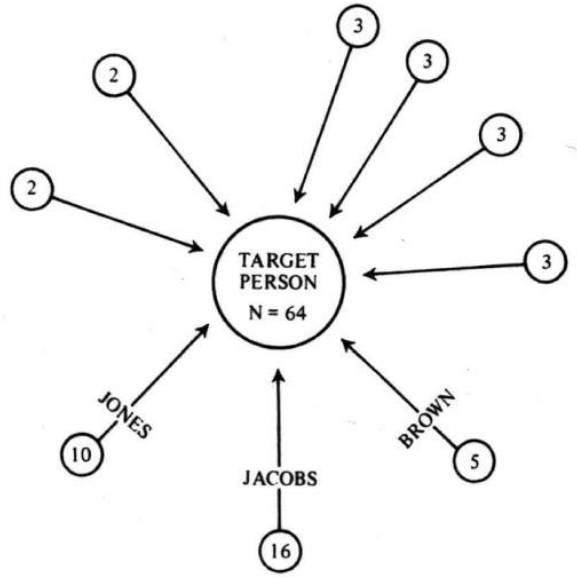


FIGURE 19.7
Convergence through common channels (includes 42 chains that started in Nebraska and 22 that started in the Boston area).

Literature: Social Psychology

- "[W]hen we state there are only 5.5 intermediate acquaintances, this connotes a closeness between the position of the starting person and the target persons, but this ~ in large measure misleading, a confusion of two entirely different frames of reference. If two persons are 5.5 removes apart, they are far apart indeed...Thus, when we speak of five intermediaries we are talking about an enormous psychological distance between the starting and target points, a distance which only seems small because we customarily regard "5" as a small, manageable quantity. We should think of the two points as being not five persons apart, but five "circles of acquaintances" apart-five "structures" apart. This helps to set it in its proper perspective."



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