

Name: _____

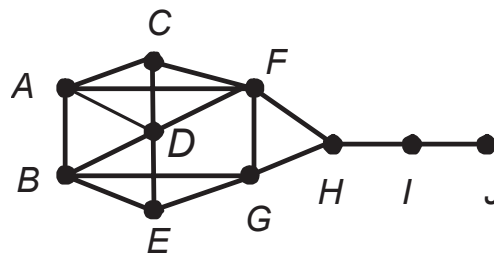
Date: _____

NUMB3RS Activity: It's All Connected

The FBI is investigating a series of killings of members of the East Side Gang. Agent Don Eppes suspects that these killings are more than random acts of retaliation, so he asks for Charlie's assistance. They want to determine who the next target might be, and who is providing a rival gang with information about who to kill to have the greatest impact on the East Side Gang. Charlie suggests that through **social network analysis**, he may be able to help.

Social network analysis uses a network to model how information flows within a group. A **network** is a map that consists of **nodes** (vertices) representing the individuals in a group and **links** (edges) connecting the nodes to show the flow of information.

Suppose that the members of the gang are Antony, Bernard, Carmon, Damion, Edwin, Fredrico, Garfield, Harry, Ivan, and Jake. The network below shows how information travels in the East Side Gang. (Each letter represents the gang member whose name begins with that letter. Each link shows which members share information, and the information can be shared in both directions.)



[Source: <http://www.orgnet.com/sna.html>]

1. A **shortest path matrix** is a matrix that shows the fewest number of links between connected people (nodes). Using the network above, complete the shortest path matrix for the East Side Gang. The row for Antony has been completed for you.

Shortest Path Matrix

	Antony	Bernard	Carmon	Damion	Edwin	Fredrico	Garfield	Harry	Ivan	Jake
Antony	0	1	1	1	2	1	2	2	3	4
Bernard										
Carmon										
Damion										
Edwin										
Fredrico										
Garfield										
Harry										
Ivan										
Jake										

Once Charlie has made the network and the shortest path matrix, he can analyze them to help determine who the most important members of the gang are, and who the next victim(s) might be.

2. One measure used to analyze a network is **degree centrality**. Degree centrality measures how active a person (node) is within the network. To find the degree centrality of a person or member, divide the number of direct connections (1-links) to other members by the total number of members he or she could be connected to.

In the network of the East Side Gang, each person can be connected to 9 other members. *A* has four 1-link connections, so the degree centrality of *A* is $\frac{4}{9} \approx 0.44$.

- a. Use the shortest path matrix you created in question 1 to determine the degree centrality of each person.

Node	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>F</i>	<i>G</i>	<i>H</i>	<i>I</i>	<i>J</i>
Degree Centrality	0.44									

- b. Which gang member(s) appear to be the most active? _____

3. Another measure that could be used to analyze a network is **closeness centrality (closeness)**. Closeness measures how easily a member connects with all other members in the network. Only links in the *shortest* path to each member are counted when finding closeness. The greater the closeness centrality, the more easily that person can interact with *all* the other members of the gang. To find the closeness of a member, use the formula

$$\text{Closeness} = \frac{n - 1}{(l_1 \cdot 1) + (l_2 \cdot 2) + (l_3 \cdot 3) + \dots}$$

where n is the number of members in the network, l_1 is the number of 1-link connections, l_2 is the number of 2-link connections, l_3 is the number of 3-link connections, etc.

In the network of the East Side Gang, there are 10 members. *A* has four 1-link connections, three 2-link connections, one 3-link connection, and one 4-link connection.

So, the closeness of *A* is $\frac{10 - 1}{(4 \cdot 1) + (3 \cdot 2) + (1 \cdot 3) + (1 \cdot 4)} = \frac{9}{4 + 6 + 3 + 4} = \frac{9}{17} \approx 0.53$.

- a. Use the shortest path matrix you created in question 1 to determine the closeness centrality of each member.

Node	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>F</i>	<i>G</i>	<i>H</i>	<i>I</i>	<i>J</i>
Closeness Centrality	0.53									

- b. Which gang member(s) appear to be the best connected? _____

4. Charlie tells Don that he has a likely target based on his analysis of the network. Who do you think Charlie suggested? Why?
5. While some members of the gang may not appear to be well connected within the gang, they may get and share information with others outside the gang. They are referred to as **peripheral players**. Suppose that Jake was once a member of a rival gang. Charlie suspects that Jake is getting information from an East Side Gang member and leaking the information to the rival gang. Which East Side Gang member is the most likely to be giving this information to Jake? Why?