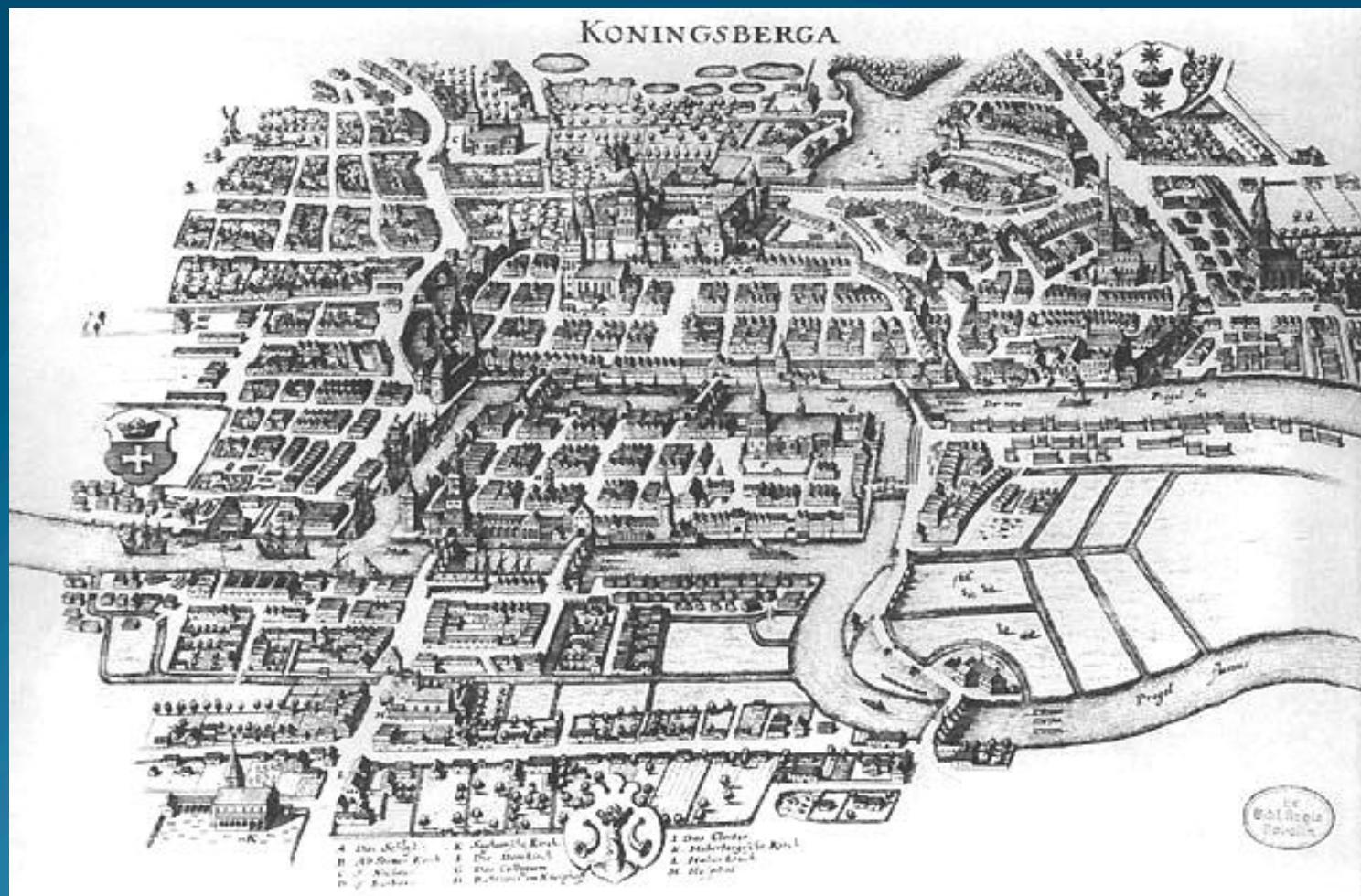
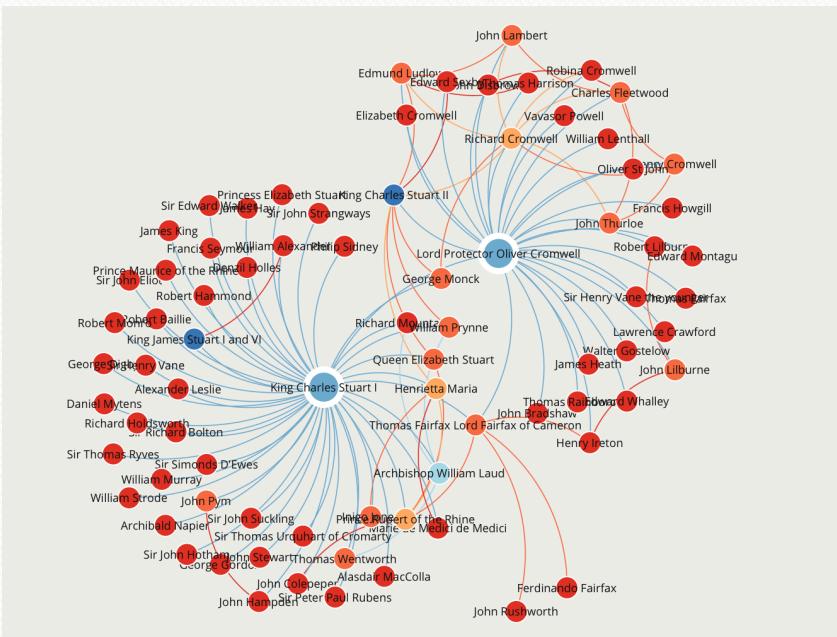


# Varieties of Networks

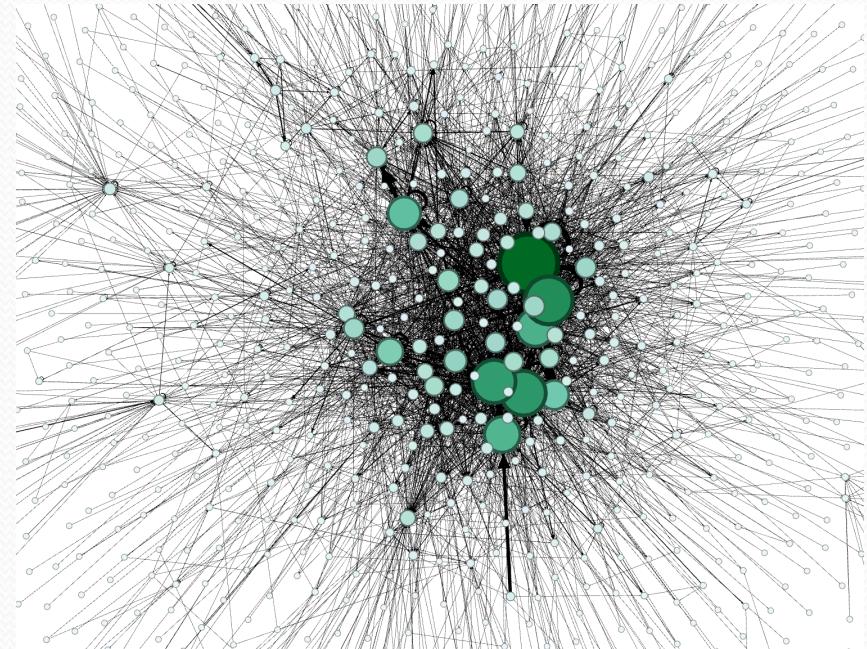
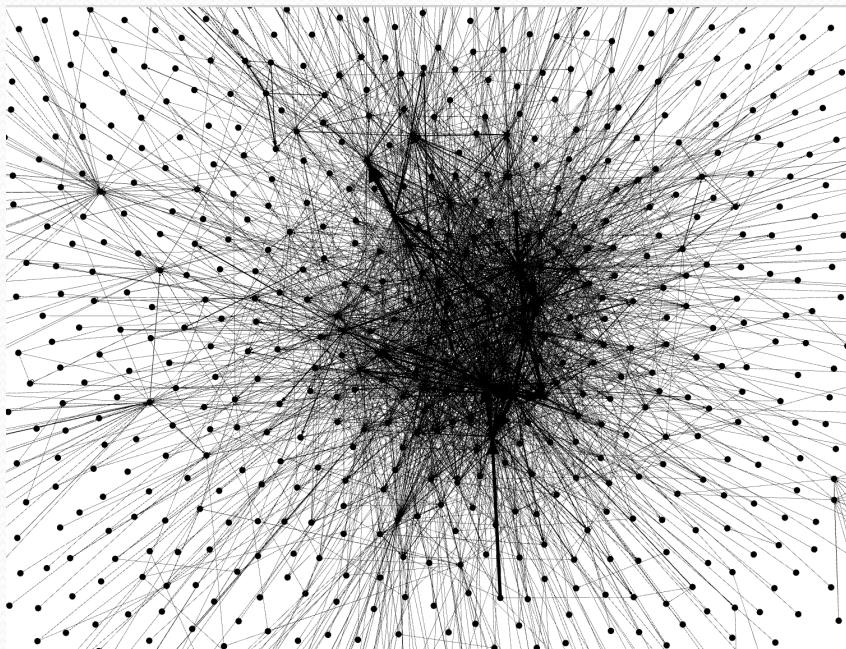


# So What Are Networks?



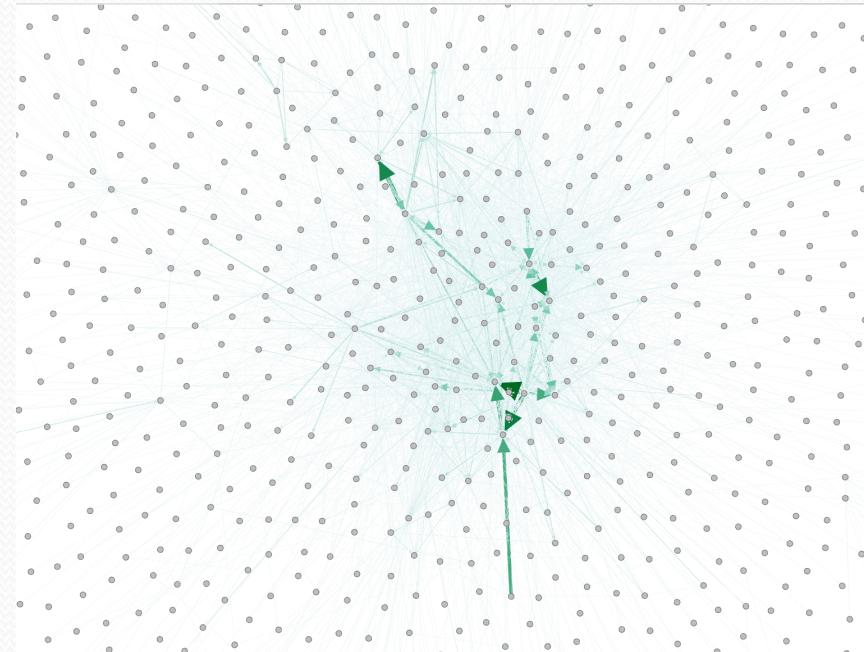
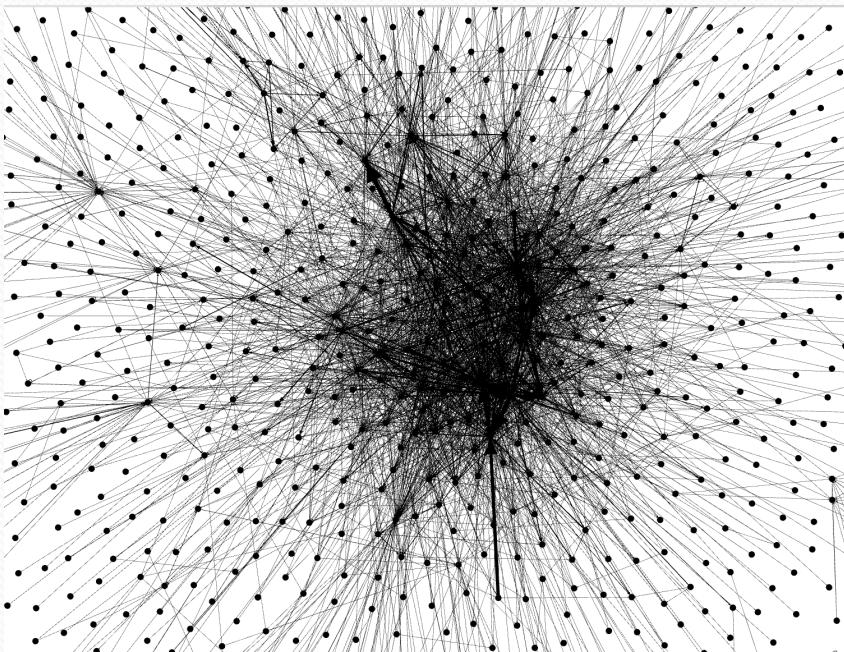
- nodes/vertices: things that are connected
  - scholars
  - cities
  - disease victims
- edges: things that connect
  - publications
  - roads
  - disease vectors

# Node Attributes: #Shax2019



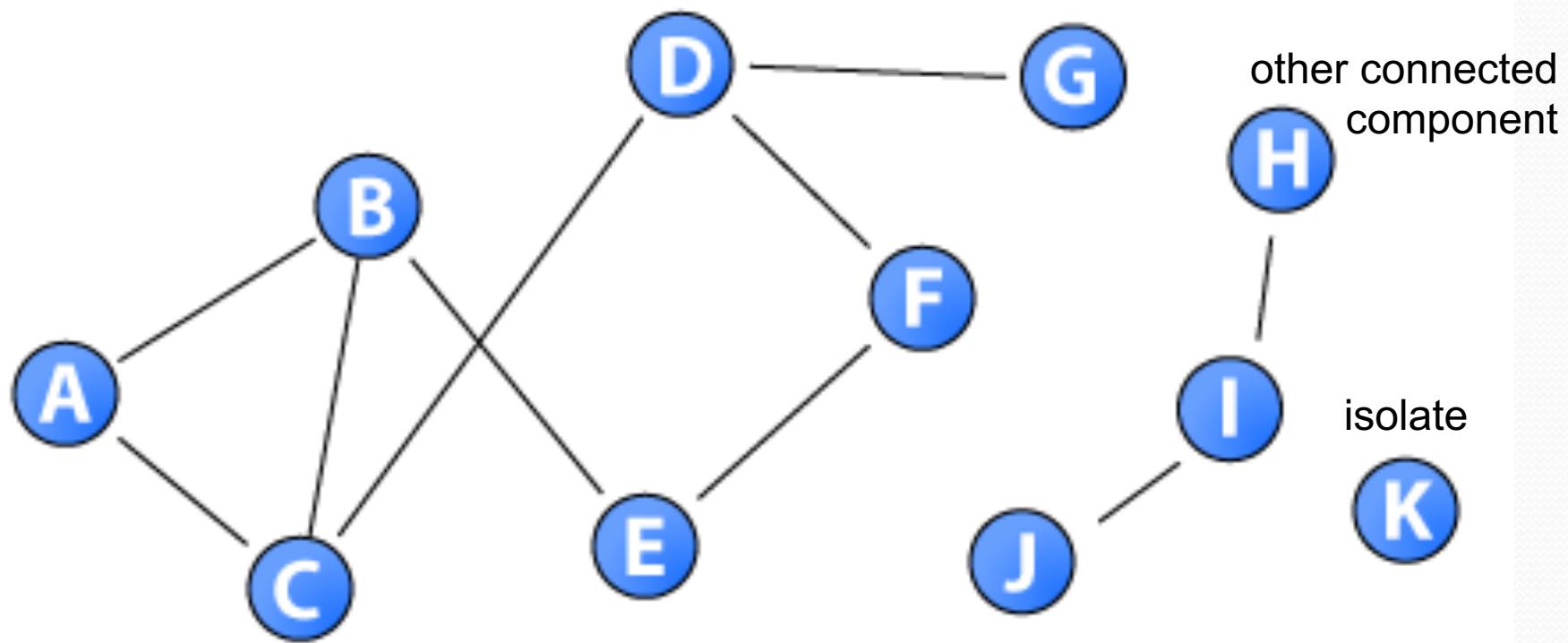
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# Edge Attributes: #Shax2019



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# Network Connectivity

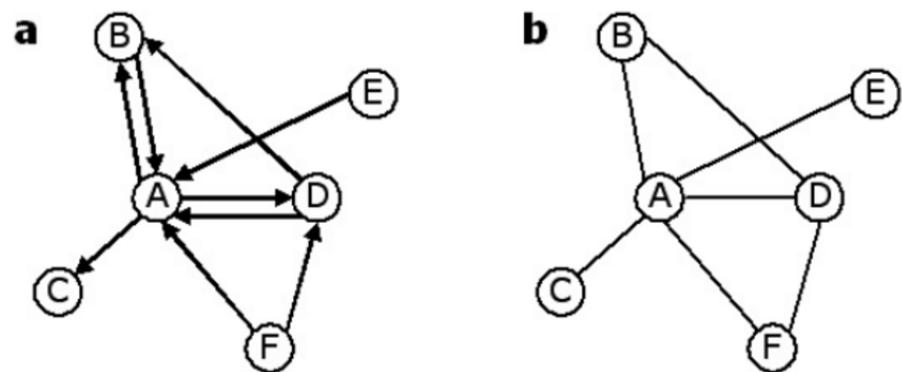


large connected component

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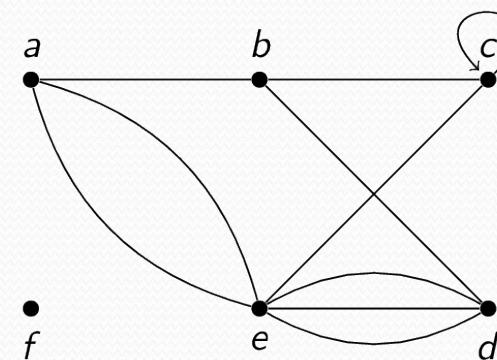
# Different Types of Networks

- for your edges, does direction matter?
  - yes: directed
    - tweets
    - rivers
    - divided highways
  - no: undirected
    - Facebook friends
    - co-authorship
    - back country roads



# Different Types of Networks

- do you allow self-loops?
  - yes: you replying to your own tweet
  - no: you cannot be Facebook friends with yourself (unless you sneak through with a fake account!)
- do you allow multiple edges between same nodes?
  - yes: you tweet to the same person multiple times
  - no: you only “friend” someone once



$$\deg a = 3$$

$$\deg b = 3$$

$$\deg c = 4$$

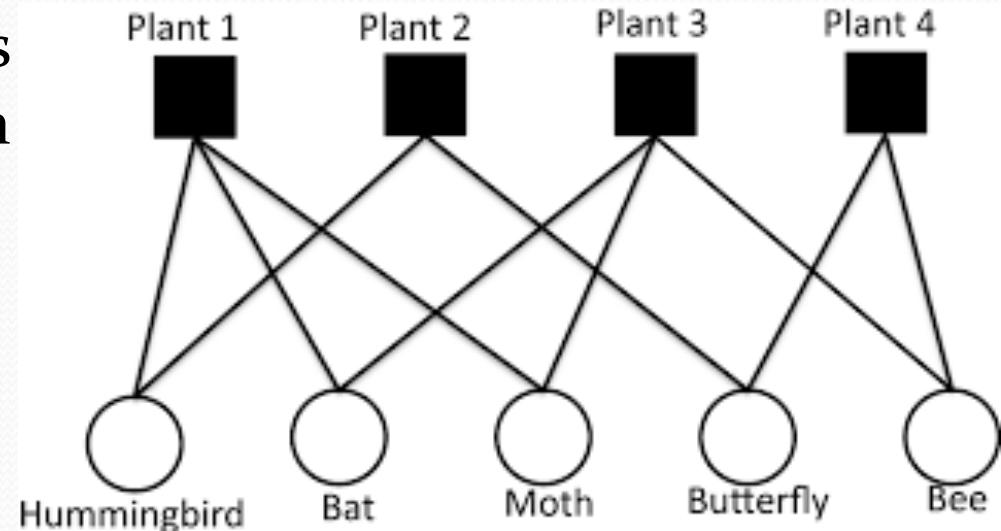
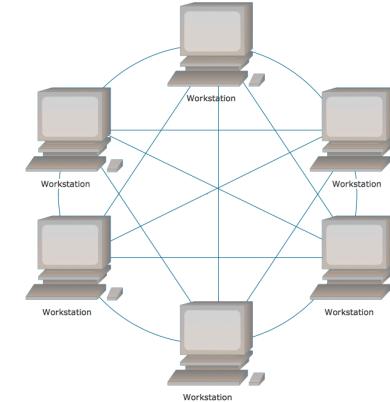
$$\deg d = 4$$

$$\deg e = 6$$

$$\deg f = 0$$

# Different Types of Networks

- are all your nodes the same type of “thing”?
  - yes: any node can connect to any other node
  - no: only certain nodes can connect to certain other types of nodes
    - bi-partite
    - k-partite



# If Complexity, Then Harder Math

**`betweenness_centrality(G, nodes)`** [\[source\]](#)

Compute betweenness centrality for nodes in a bipartite network.

Betweenness centrality of a node  $v$  is the sum of the fraction of all-pairs shortest paths that pass through  $v$ .

Values of betweenness are normalized by the maximum possible value which for bipartite graphs is limited by the relative size of the two node sets [1].

Let  $n$  be the number of nodes in the node set  $U$  and  $m$  be the number of nodes in the node set  $V$ , then nodes in  $U$  are normalized by dividing by

$$\frac{1}{2}[m^2(s+1)^2 + m(s+1)(2t-s-1) - t(2s-t+3)],$$

where

$$s = (n-1) \div m, t = (n-1) \mod m,$$

and nodes in  $V$  are normalized by dividing by

$$\frac{1}{2}[n^2(p+1)^2 + n(p+1)(2r-p-1) - r(2p-r+3)],$$

where,

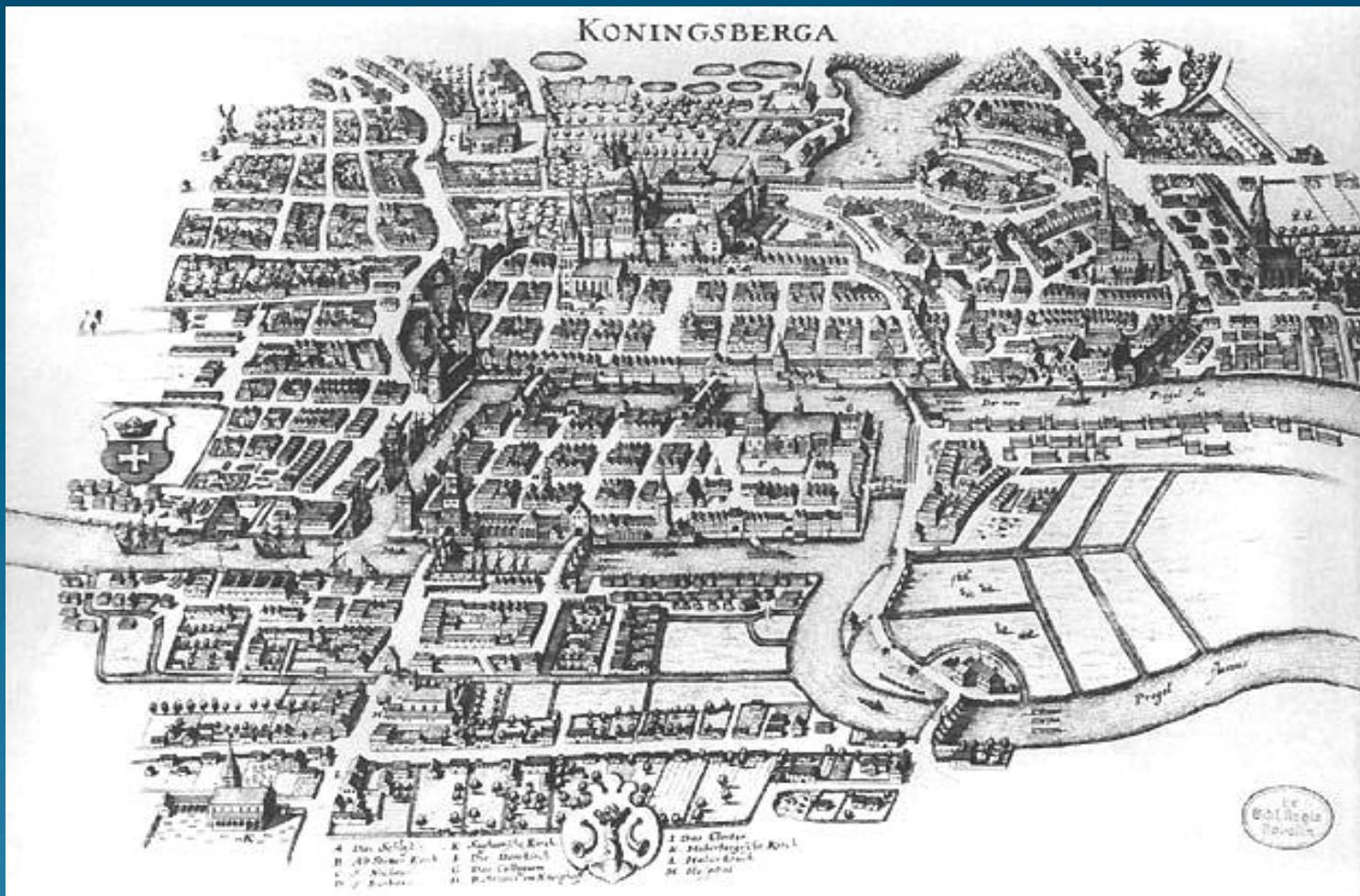
$$p = (m-1) \div n, r = (m-1) \mod n.$$

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# Choose Your Own Adventure

- what are your nodes? what are your edges?
- is your network k-partite or unipartite?
- is your network connected? how many components can it have?
- is your network directed or undirected?
- do you allow self loops? multiple edges? weighted edges?
- what quantitative and qualitative attributes do your nodes and edges have?

# How Do You Structure Data?



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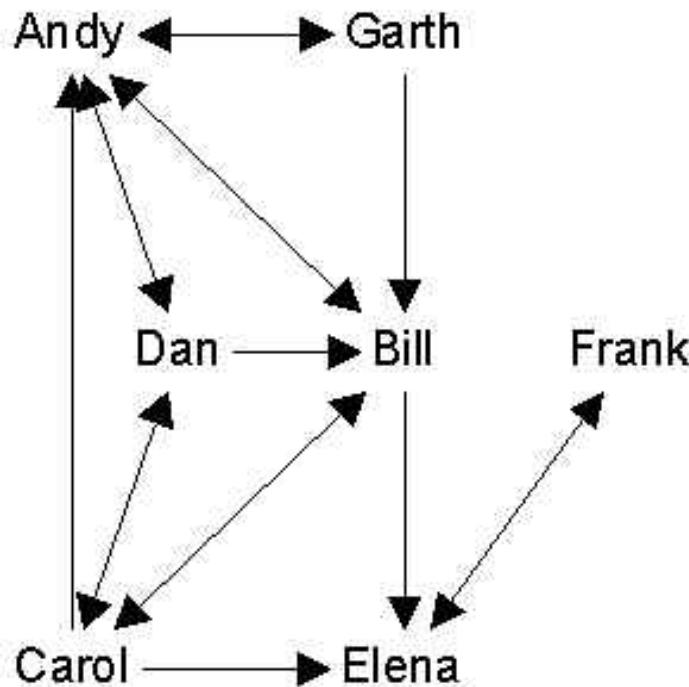
# CAUTION: MATH ALERT

## Adjacency Matrix

		Participants																							
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Participants		1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0	1	1	1	1	1	0
A	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0	1	1	1	1	1	0	
B	1	1	0	1	1	1	0	0	0	1	1	0	0	1	0	0	0	0	0	1	1	1	0	0	
C	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	
D	1	0	1	1	1	1	0	1	1	1	1	0	1	1	0	0	1	1	1	1	1	0	0	1	
E	1	1	1	1	1	1	0	1	1	1	1	0	0	1	0	0	0	1	1	1	1	1	0	1	
F	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	
G	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
H	1	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	0	1	0	0	0	1	0	0	
I	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	
J	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	
K	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	
L	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1	0	0	0	1	1	1	1	0	1	
M	0	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	0	0	0	1	1	0		
N	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0		
O	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
P	0	0	1	0	0	1	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	0	
Q	0	0	1	0	0	1	1	1	1	1	1	0	1	1	1	1	0	1	0	0	0	1	0	0	
R	0	0	1	1	0	1	1	0	1	1	1	0	1	1	1	1	0	1	0	0	0	1	1	0	
S	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0		
T	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	0	0	1	1	1	0	1		
U	1	1	0	1	1	1	1	0	1	1	1	1	0	0	1	0	0	0	1	1	0	1	0		
V	1	1	1	0	1	1	1	0	1	1	1	1	0	1	1	1	0	0	1	1	0	0	1		
W	0	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	0	1	0		
X	1	0	1	1	1	1	0	1	1	1	1	1	1	0	1	1	0	1	0	1	0	1	0		
Y	0	1	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0		

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# Graph vs. Matrix



	And	Bil	Car	Dan	Ele	Fra	Gar
Andy		1	0	1	0	0	1
Bill	1		1	0	1	0	0
Carol	1	1		1	1	0	0
Dan	1	1	1		0	0	0
Elena	0	0	0	0		1	0
Frank	0	0	0	0	1		0
Garth	1	1	0	0	0	0	

# How Do You Structure Data For Them?

- node list (optional) + edge list
- nodes: unique identifiers
- nodes: attributes

SDFB Person ID	ODNB ID	Prefix	First Name	Last Name	Suffix	Title	Birth Year Type	Birth Year	Death Year Type	Death Year	Historical Significance
10000001	16081		John	A Lasco		In	1499	In	1560		evangelical reformer
10000002	14346		Iaco	ab Dewi		In	1647	In	1722		copyist and translator
10000003	48541		Dafydd	ab Edmwnd		Before	1450	After	1500		poet
10000004	93721		Dafydd	ab Ieuan ab Iorwerth		After	1393	Before or In	1503		abbot of Valle Crucis and bishop of St Asaph

# How Do You Structure Data For Them?

- node list + edge list
- directed edges have a “source” and a “target”
- undirected edges treat source and target as interchangeable
- edges: reference nodes’ unique identifiers
- edges: attributes

10007097	10011701	0.95
10007097	10012116	0.8
10007097	10012176	0.48
10007097	10012867	0.62
10007097	10013746	0.62
10007097	10014062	0.38
10007097	10014339	0.57
10007097	10014822	0.52
10007097	10015464	0.65
10007097	10015494	0.48
10007097	10015558	0.38
10007097	10015835	0.42
10007097	10015955	0.52
10007097	10017023	0.48
10007097	10017587	0.78
10007097	10017667	0.5
10007097	10018076	0.88
10007097	10018836	0.42
10007097	10019463	0.35
10007097	10020166	0.48
10007097	10020778	0.6
10007097	10020946	0.52
10007097	10021623	0.3
10007097	10021768	0.5
10007097	10021908	0.45
10007097	10022282	0.65

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# Edge List with Unique Identifiers

source	target
Shxperienced	Exhaust_Fumes
prof_nmehdiz	DrDadabhoj
prof_nmehdiz	NicoleSheriko
dmbblank	dnmcinnis
dmbblank	dnmcinnis
dmbblank	dnmcinnis
callanjd	andykesson
callanjd	B4Shakes
gwayvt	Exhaust_Fumes
gwayvt	_theBrownprint_
gwayvt	HamletHologram
KathrynVSantos	ProfOLeary
KathrynVSantos	noraj_williams
KathrynVSantos	charlenevsmith
Shakespeare	_BenJonson_
Shakespeare	_BenJonson_
Shakespeare	Shakespeare
mollsywhat	dr_pangallo
gwayvt	ReadColleenK
lyn_tribble	DRosvally
lyn_tribble	GinaBloom5
_BenJonson_	Shakespeare
lyn_tribble	Exhaust_Fumes
RadioTaskForce	roaringgirle
pagestostages	ReadColleenK
e_ekelly	Exhaust_Fumes
e_ekelly	MaloneSociety
owilliamsdc	ReadColleenK
JonathanHsy	ReadColleenK
Exhaust_Fumes	ReadColleenK
brandywill	Exhaust_Fumes
andykesson	Exhaust_Fumes
emeramchugh	Exhaust_Fumes
Exhaust_Fumes	MaloneSociety
16thCenturyGirl	shakespearectr

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