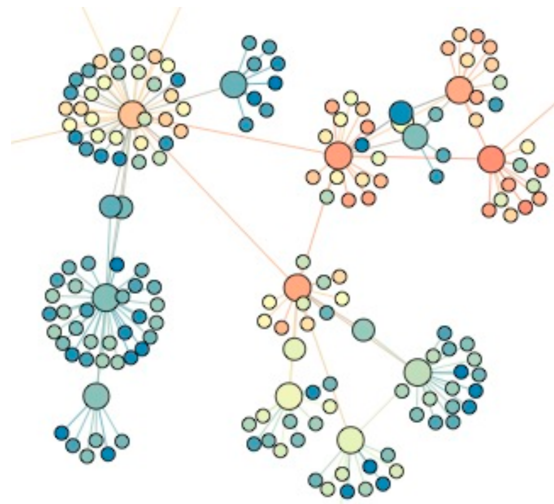


SNA 6: processes on networks

Lada Adamic

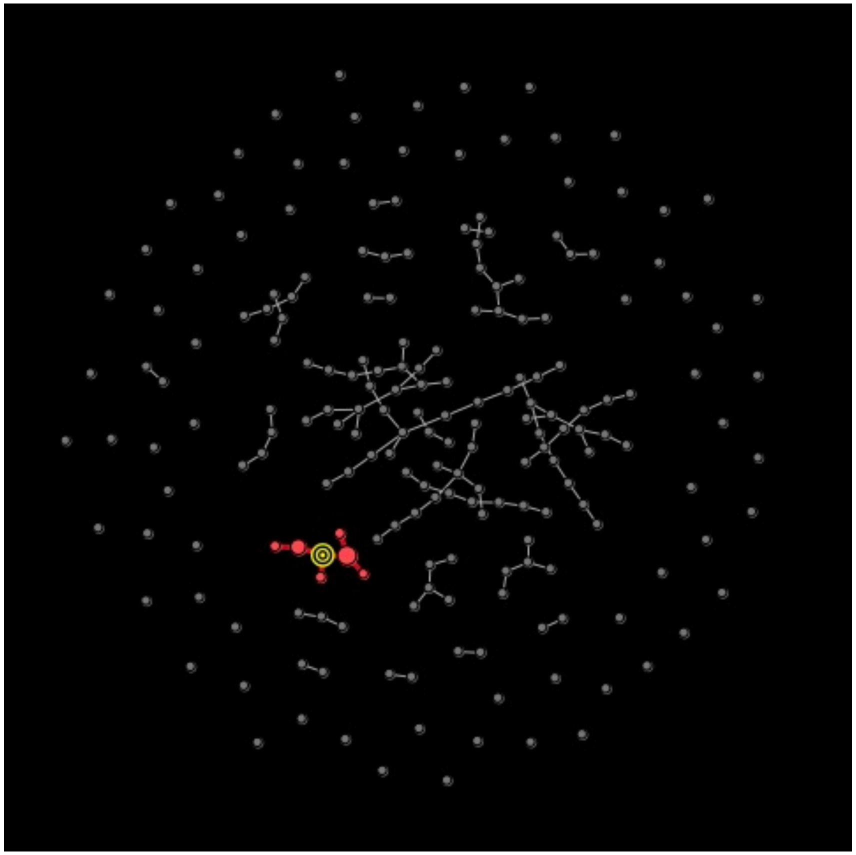
school of information

Processes on networks

- Diffusion (simple)
  - ER graphs
  - Scale-free graphs
  - Small-world topologies
- Complex contagion/thresholds
- Collective action
- Innovation
- Problem solving

Diffusion in networks: ER graphs

- review: diffusion in ER graphs

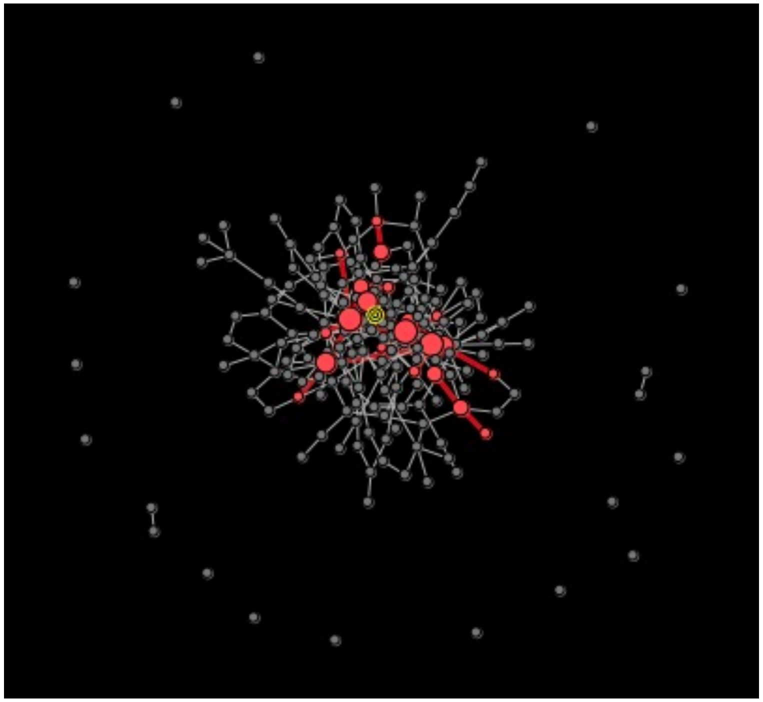


http://www.ladamic.com/netlearn/NetLogo501/ERDiffusion.html

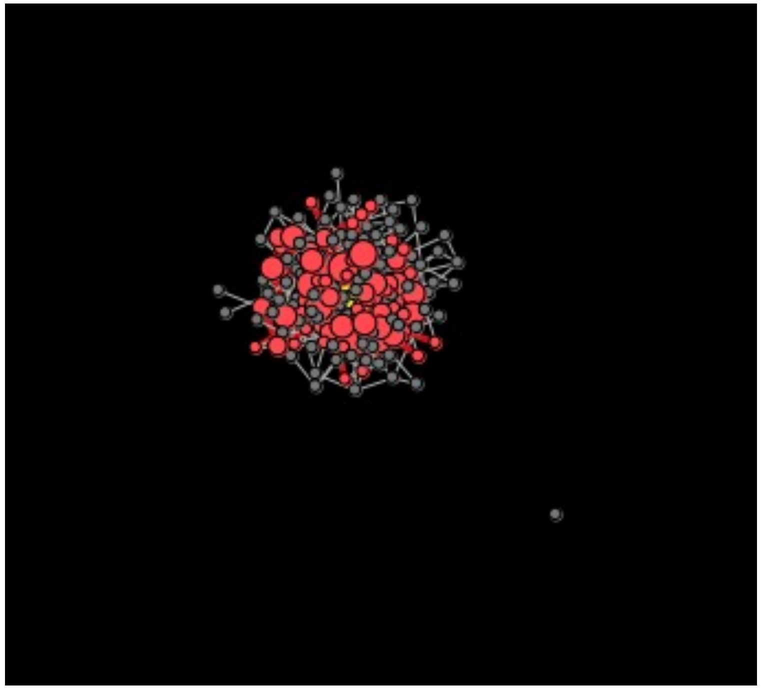
ER graphs: connectivity and density

nodes infected after 10 steps, infection rate = 0.15

average degree = 2.5



average degree = 10

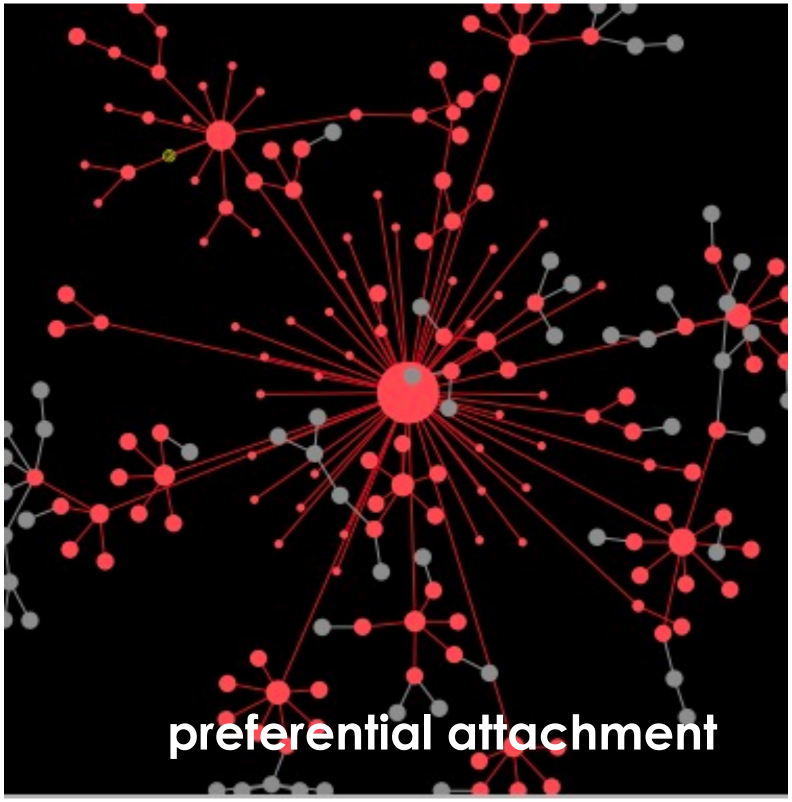


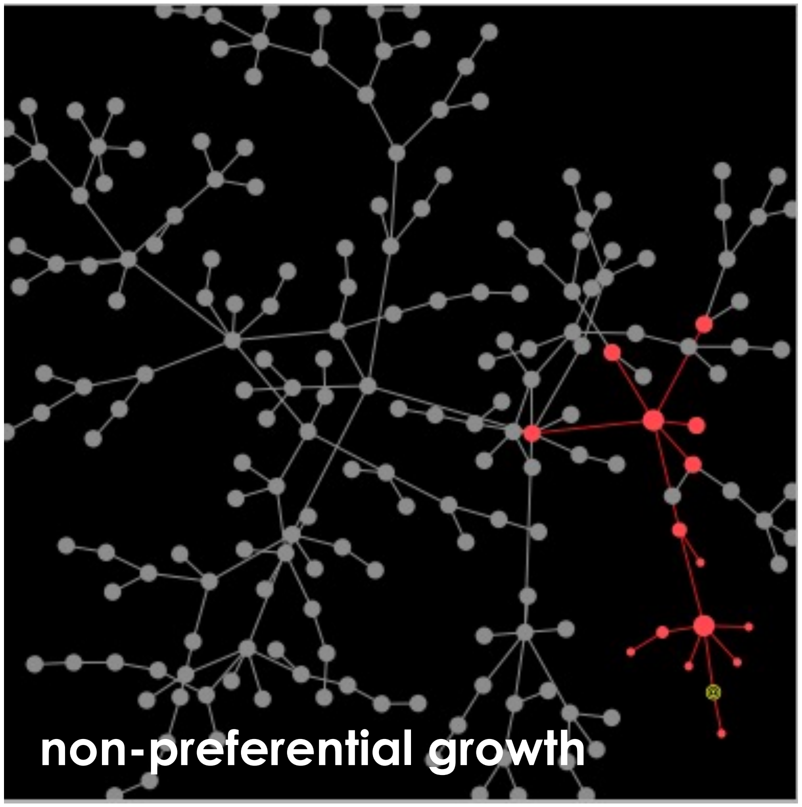
Quiz Q:

- When the density of the network increases, diffusion in the network is
  - faster
  - slower
  - unaffected

Diffusion in “grown networks”

- nodes infected after 4 steps, infection rate = 1





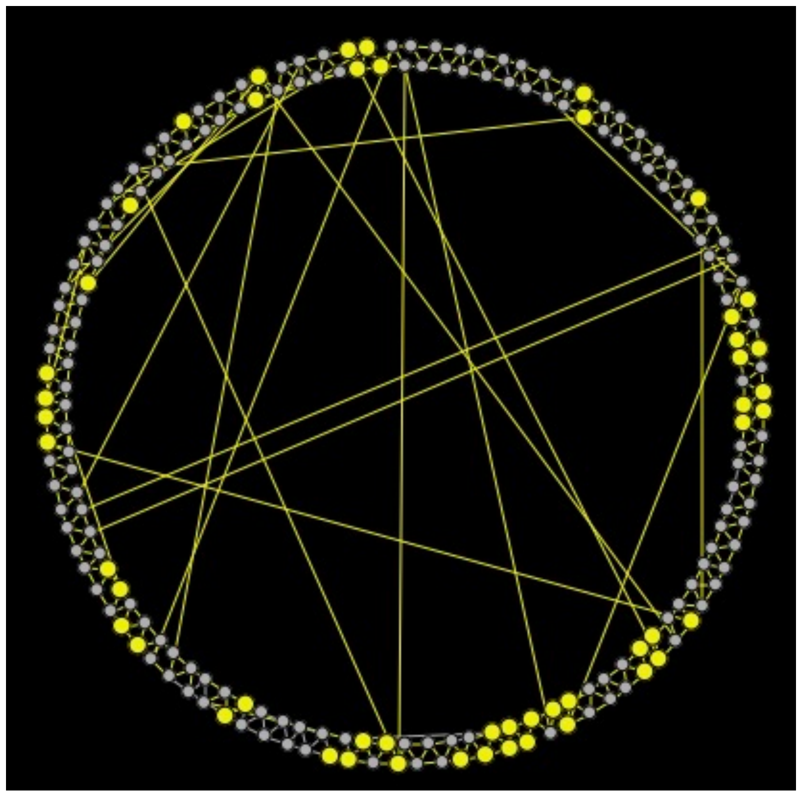
http://www.ladamic.com/netlearn/NetLogo501/BADiffusion.html

Quiz Q:

- When nodes preferentially attach to high degree nodes, the diffusion over the network is
  - faster
  - slower
  - unaffected

Diffusion in small worlds

- What is the role of the long-range links in diffusion over small world topologies?



http://www.ladamic.com/netlearn/NetLogo4/SmallWorldDiffusionSIS.html

Quiz Q:

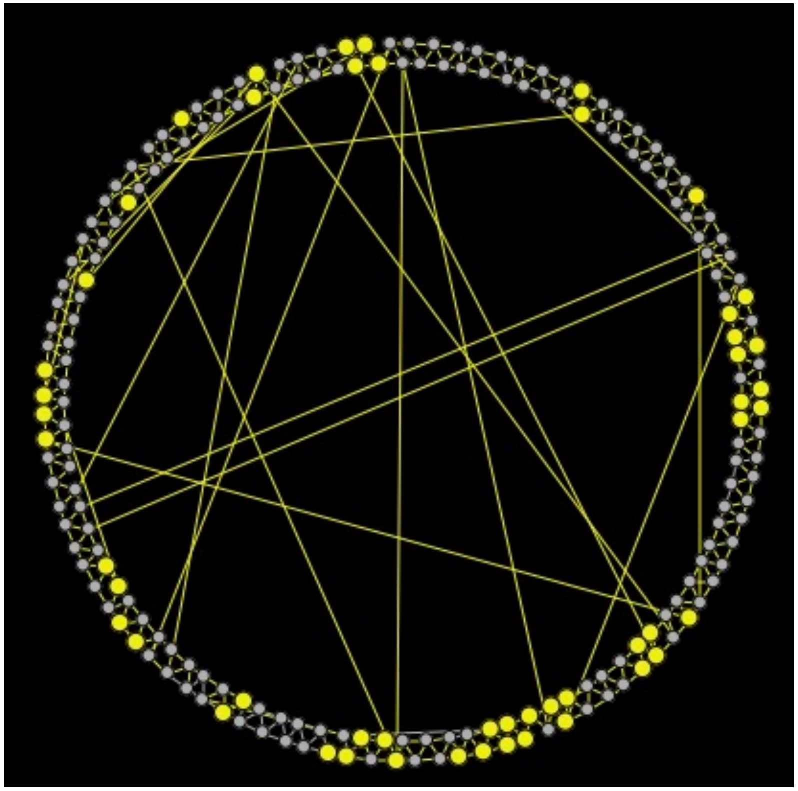
- As the probability of rewiring increases, the speed with which the infection spreads
  - increases
  - decreases
  - remains the same

Simple vs. complex contagion

- Simple contagion: each friend infects you with some probability for each unit of time
- Complex contagion: you will only take action if a certain number or fraction of your neighbors do

What is the role of the shortcuts?

- long range links unlikely to coincide in influence



Quiz Q:

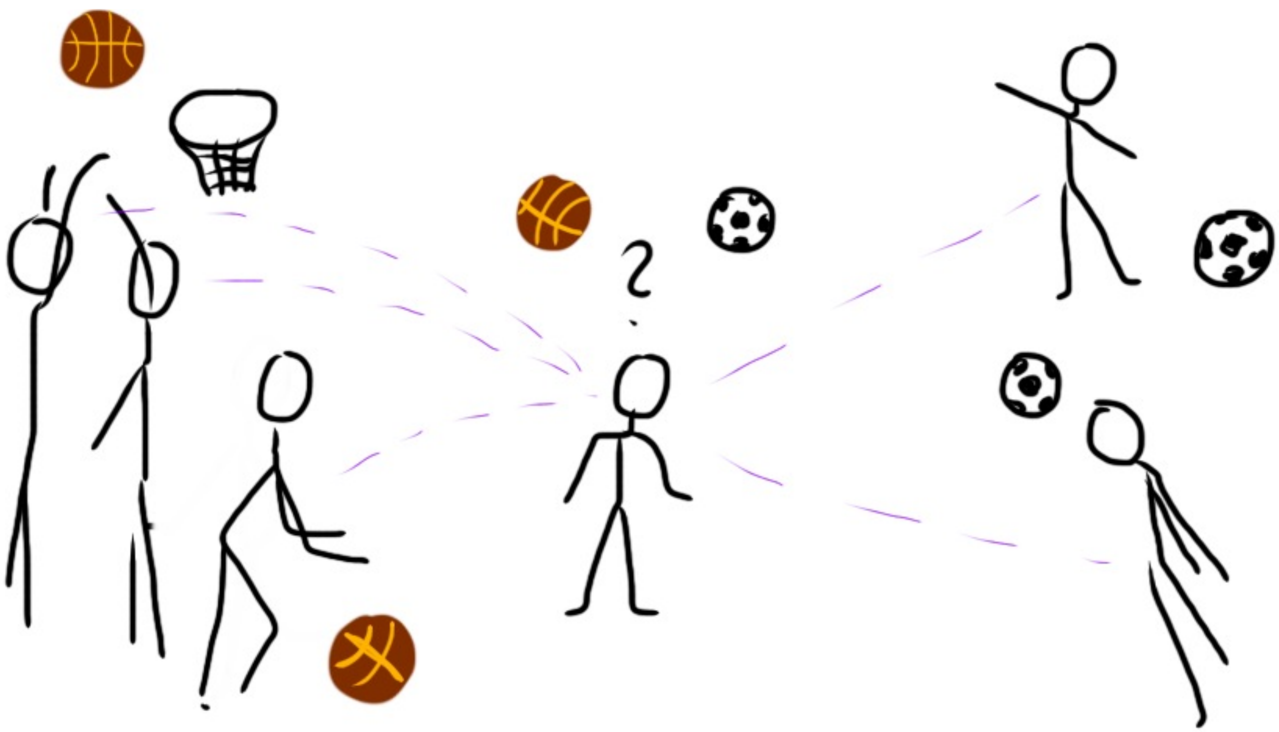
- Relative to the simple contagion process the complex contagion process:
  - is better able to use shortcuts
  - advances more rapidly through the network
  - infects a greater number of nodes

networked coordination game

- choice between two things, A and B (e.g. basketball and soccer)
- if friends choose A, they get payoff *a*
- if friends choose B, they get payoff *b*
- if one chooses A while the other chooses B, their payoff is 0

coordinating with one' s friends

Let A = basketball, B = soccer. Which one should you learn to play?

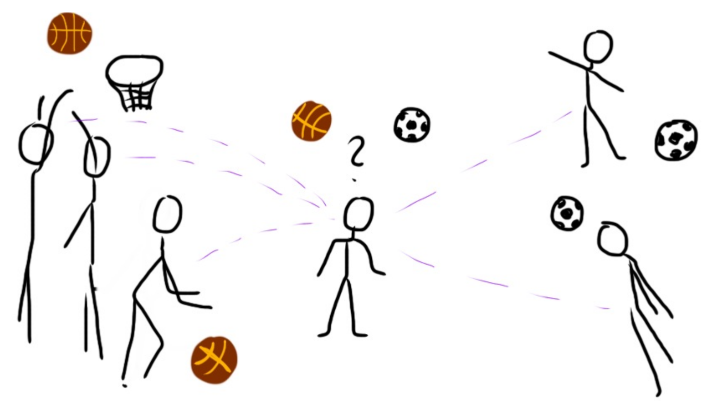


fraction p = 3/5 play basketball

fraction p = 2/5 play soccer

which choice has higher payoff?

- *d* neighbors
- *p* fraction play basketball (A)
- (1-*p*) fraction play soccer (B)
- if choose A, get payoff
  $p * d * a$
- if choose B, get payoff
  $(1-p) * d * b$
- so should choose A if
  - $p\, d\, a \geq (1-p)\, d\, b$
  - or
  - $p \geq b \;/\; (a + b)$



two equilibria

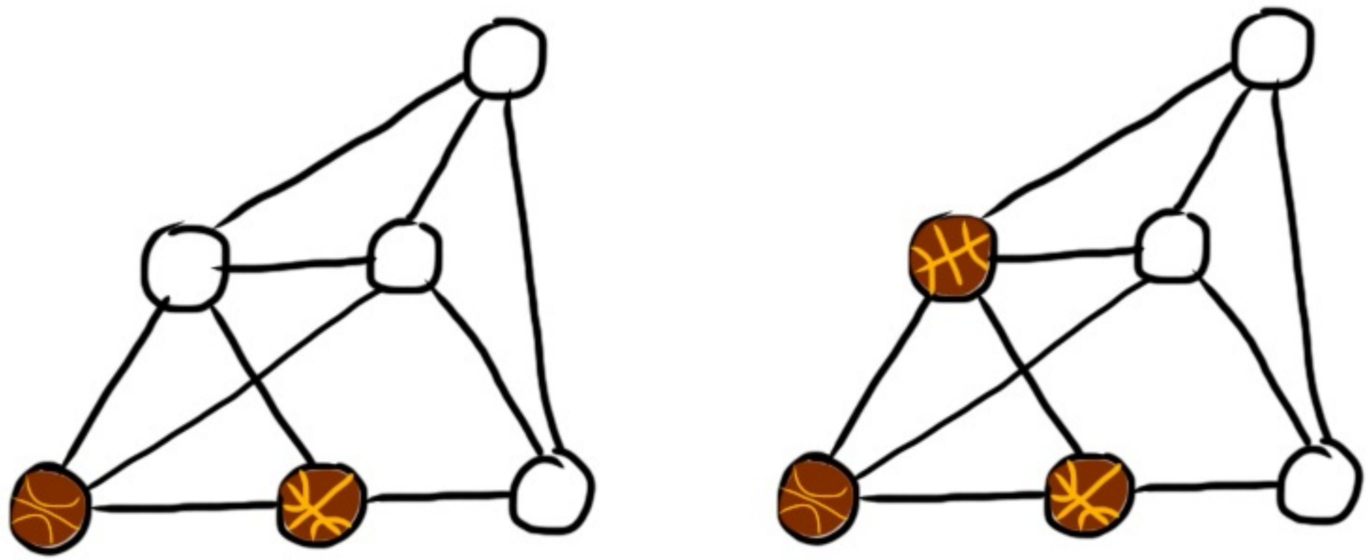
- everyone adopts A
- everyone adopts B

what happens in between?

- What if two nodes switch at random? Will a cascade occur?
- example:
  - $a = 3$, $b = 2$
  - payoff for nodes interaction using behavior A is 3/2 as large as what they get if they both choose B
  - nodes will switch from B to A if at least $q = 2/(3+2) = 2/5$ of their neighbors are using A

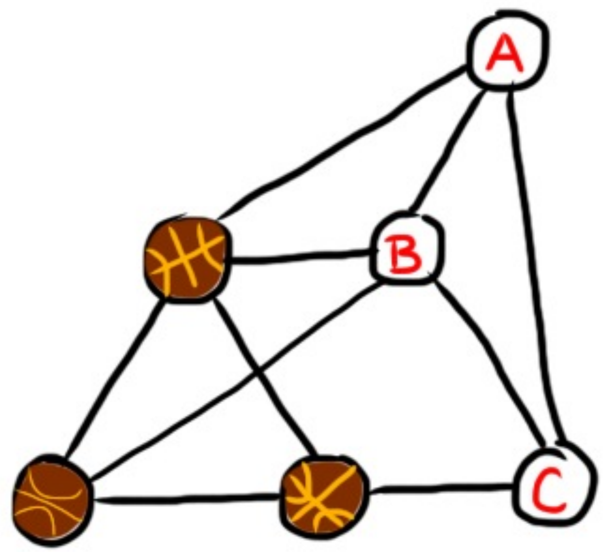
how does a cascade occur

- suppose 2 nodes start playing basketball due to external factors (e.g. they are bribed with a free pair of shoes by some devious corporation)

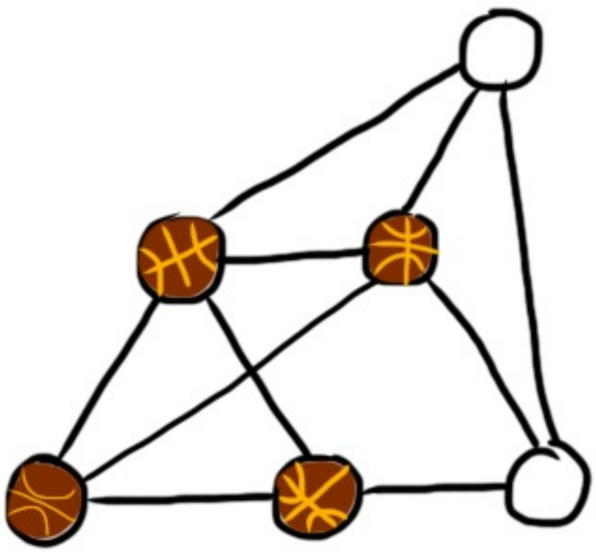


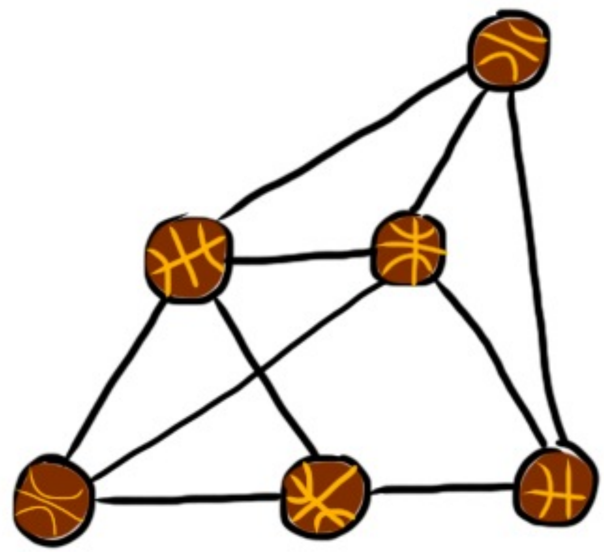
Quiz Q:

Which node(s) will switch to playing basketball next?



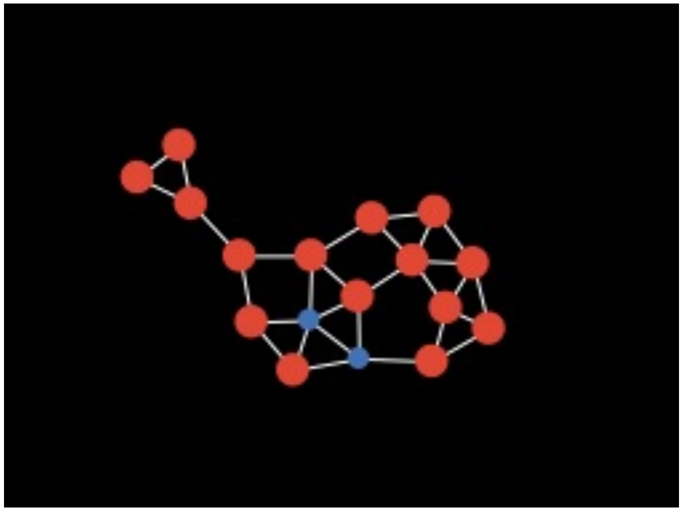
the complete cascade





you pick the initial 2 nodes

- A larger example (Easley/Kleinberg Ch. 19)
- does the cascade spread throughout the network?



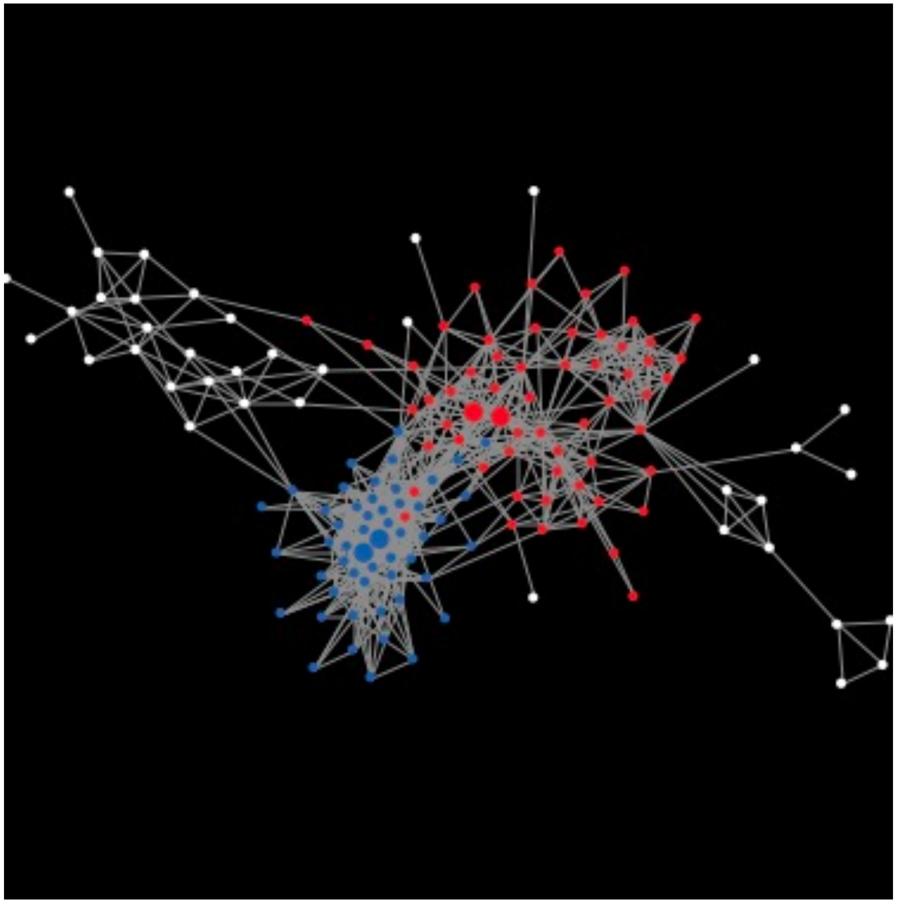
http://www.ladamic.com/netlearn/NetLogo412/CascadeModel.html

implications for viral marketing

- if you could pay a small number of individuals to use your product, which individuals would you pick?

try it on Lada's Facebook network

- you can play with a partner
- each person gets to pick 2 nodes
  - first person picks one blue
  - second person picks one red
  - first person picks an additional blue
  - second person picks an additional red



Quiz question:

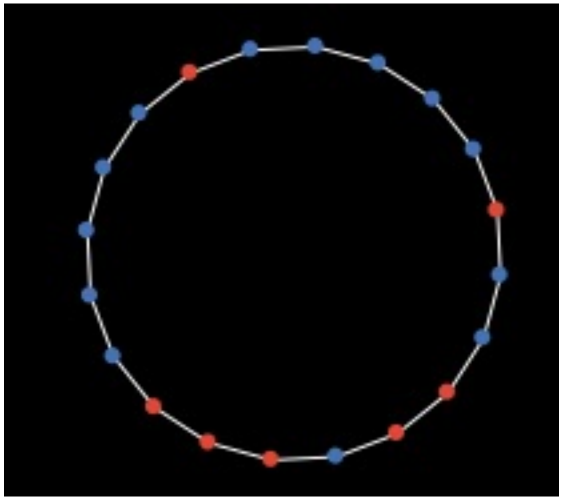
- What is the role of communities in complex contagion
  - enabling ideas to spread in the presence of thresholds
  - creating isolated pockets impervious to outside ideas
  - allowing different opinions to take hold in different parts of the network

bilingual nodes

- so far nodes could only choose between A and B
- what if you can play both A and B, but pay an additional cost c?

try it on a line

- Increase the cost of being bilingual so that no node chooses to do so. Let the cascade run
- Now lower the cost.
  - What happens?

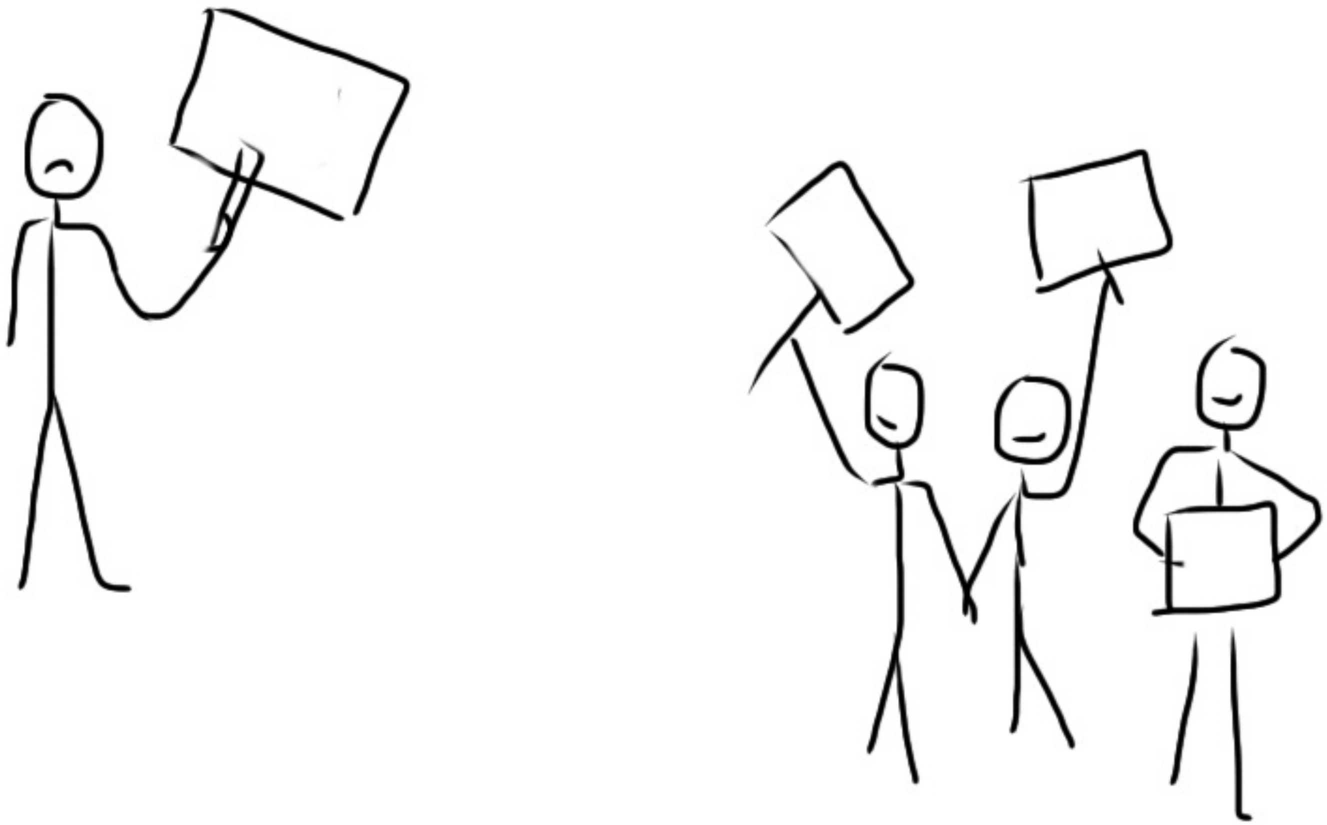


Quiz Q:

- The presence of bilingual nodes
  - helps the superior solution to spread throughout the network
  - helps inferior options to persist in the network
  - causes everyone in the network to become bilingual

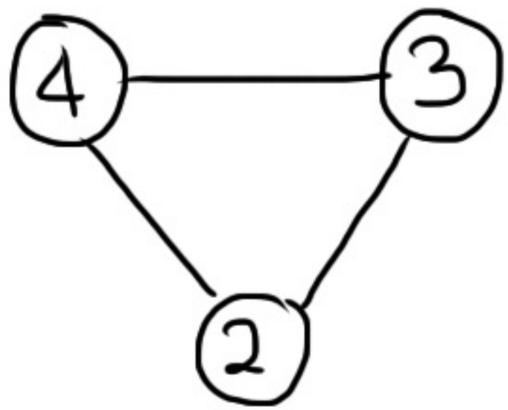
knowledge, thresholds, and collective action

- nodes need to coordinate across a network, but have limited horizons



can individuals coordinate?

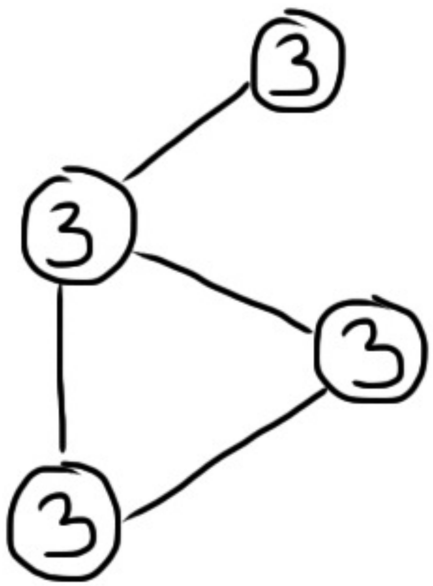
- each node will act if at least x people (including itself) mobilize



nodes will not mobilize

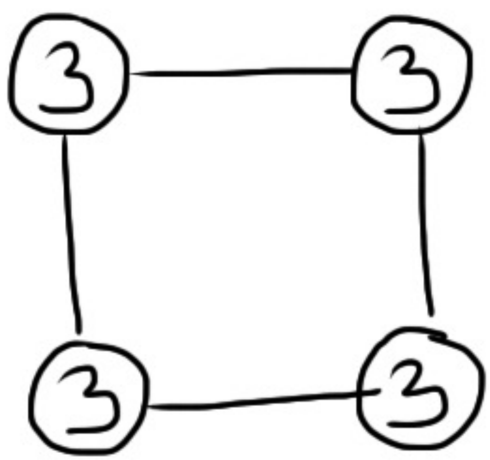
mobilization

- there will be some turnout



Quiz Q:

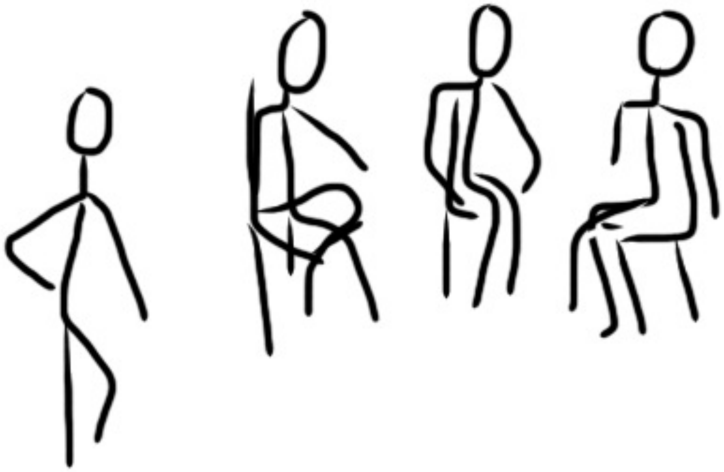
- will this network mobilize (at least some fraction of the nodes will protest)?



innovation in networks

- network topology influences who talks to whom
- who talks to whom has important implications for innovation and learning

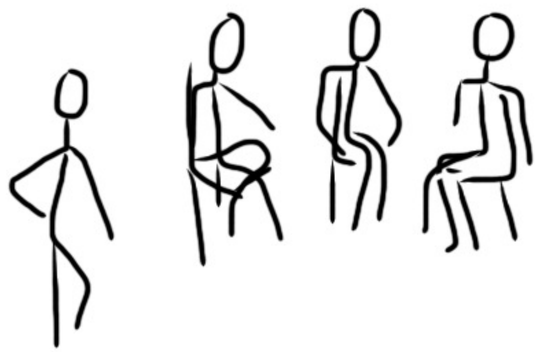
better to innovate or imitate?

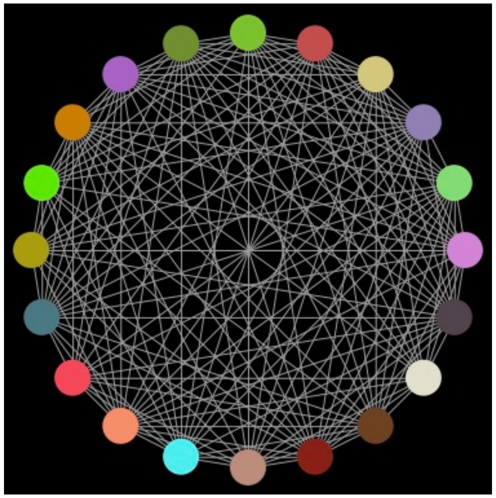


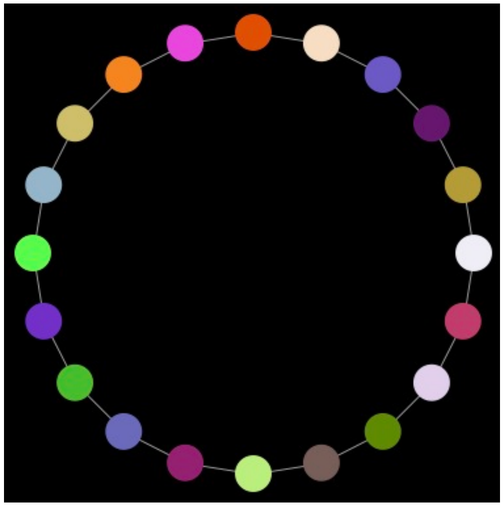
brainstorming:
more minds together,
but also danger of groupthink

working in isolation:
more independence
slower progress

in a network context



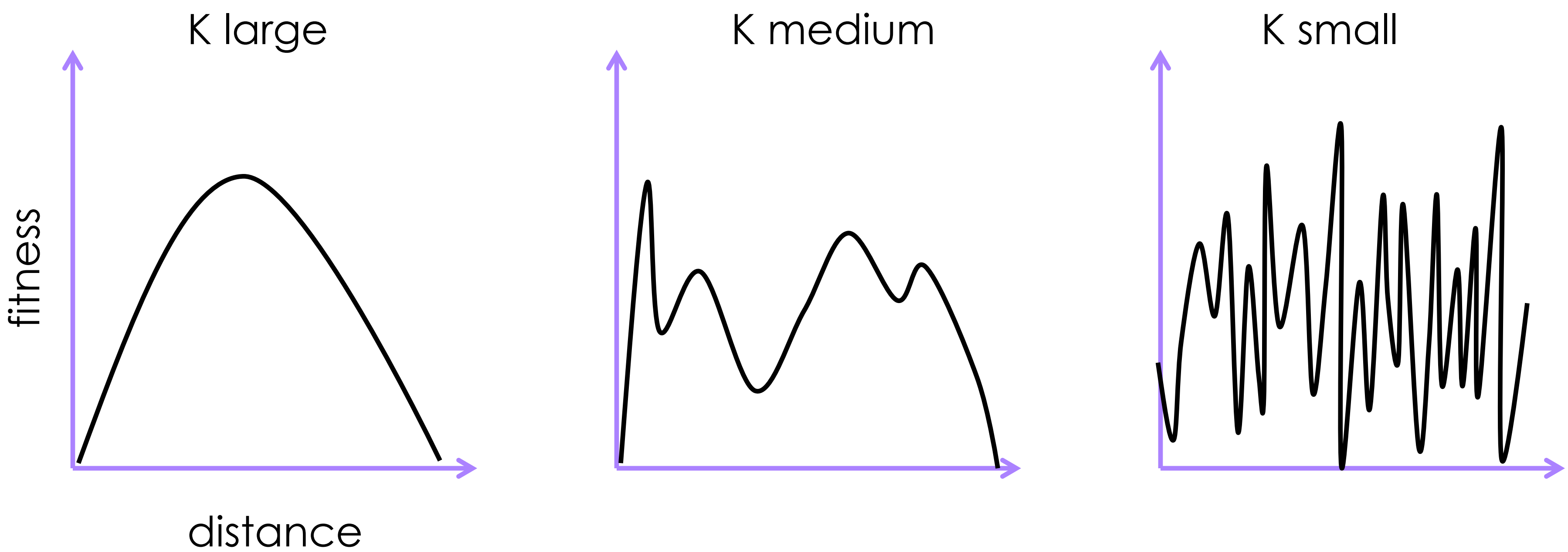




modeling the problem space

- Kauffman's NK model
- N dimensional problem space
  - N bits, each can be 0 or 1
- K describes the smoothness of the fitness landscape
  - how similar is the fitness of sequences with only 1-2 bits flipped (K = 0, no similarity, K large, smooth fitness)

Kauffman’s NK model



Update rules

- As a node, you start out with a random bit string
- At each iteration
  - If one of your neighbors has a solution that is more fit than yours, imitate (copy their solution)
  - Otherwise innovate by flipping one of your bits

Quiz Q:

- Relative to the regular lattice, the network with many additional, random connections has on average:
  - slower convergence to a local optimum
  - smaller improvement in the best solution relative to the initial maximum
  - more oscillations between solutions

Coordination: graph coloring

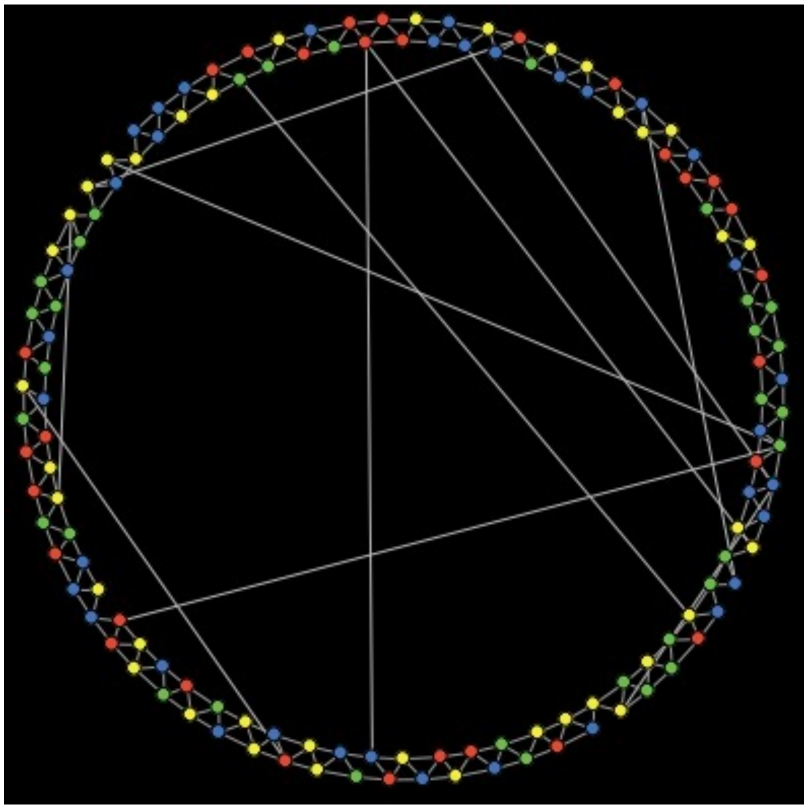
- Application: coloring a map: limited set of colors, no two adjacent countries should have the same color

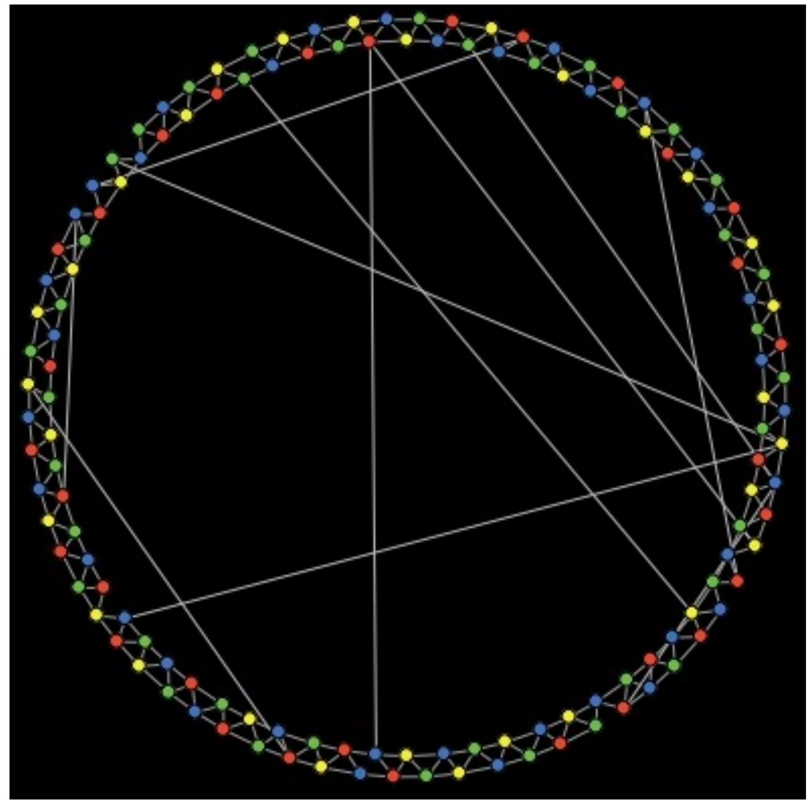
graph coloring on a network

- Each node is a human subject. Different experimental conditions:
  - knowledge of neighbors' color
  - knowledge of entire network
- Compare:
  - regular ring lattice
  - small-world topology
  - scale-free networks

Kearns et al., 'An Experimental Study of the Coloring Problem on Human Subject Networks', Science, 313(5788), pp. 824-827, 2006

simulation





Quiz Q:

- As the rewiring probability is increased from 0 to 1 the following happens:
  - the solution time decreases
  - the solution time increases
  - the solution time initially decreases then increases again

recap

- network topology influences processes occurring on networks
  - what state the nodes converge to
  - how quickly they get there
- process mechanism matters:
  - simple vs. complex contagion
  - coordination
  - learning