epidemics
[ncw ch. 21]

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Science 329, 1194-1197(2010)

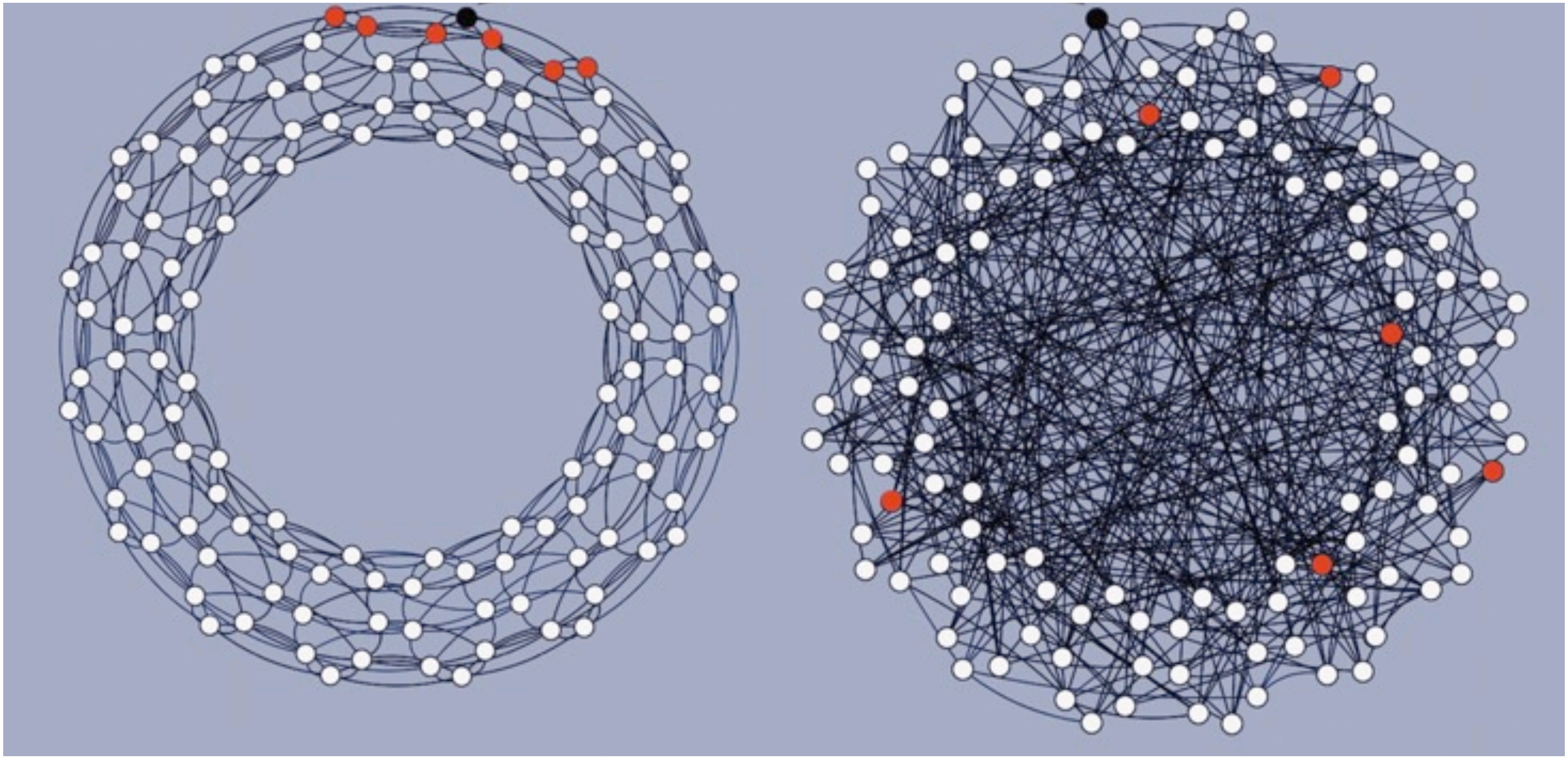
The Spread of Behavior in an Online Social Network Experiment

How does the structure of social networks affect the spread of behavior?

high clustering vs. long range jumps?

what is the most efficient and for what (eg social reinforcement)

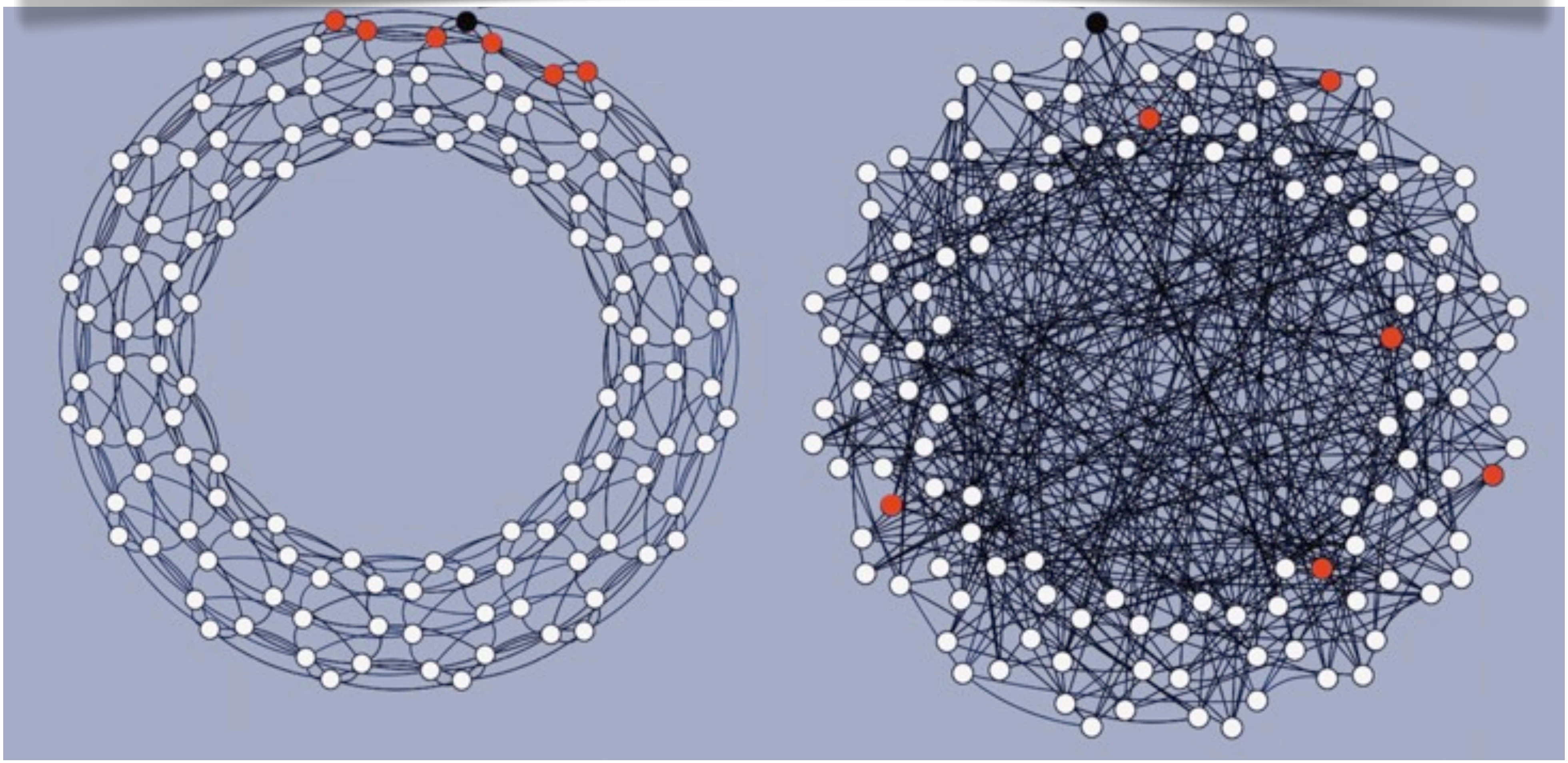
the artificial synthetic network
a clustered 6d-lattice vs random network
(single trial: N = 128 = 16 * 8, Z = 6 homogeneous degree)



rewiring

same degree sequence: in both graphs degree is the same - so locally the same for an agent

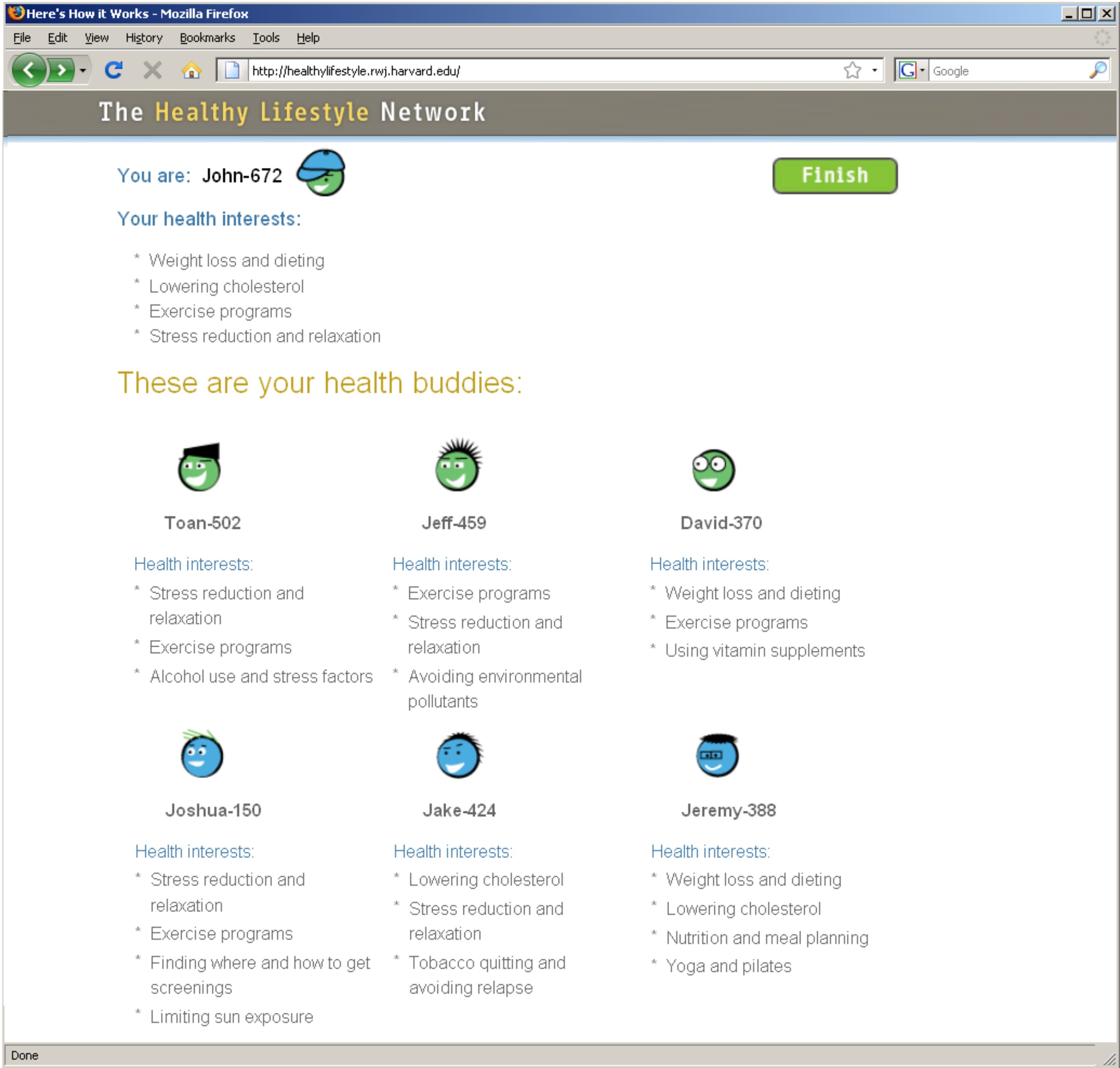
different clustering/cliquishness: in the lattice red nodes are & share neighbors with each other, not in the randomly rewired network - how would you rewire/randomize the left graph?



Any differences in the dynamics of diffusion between the two conditions can be attributed to the effects of network topology

3 other factors to consider ...

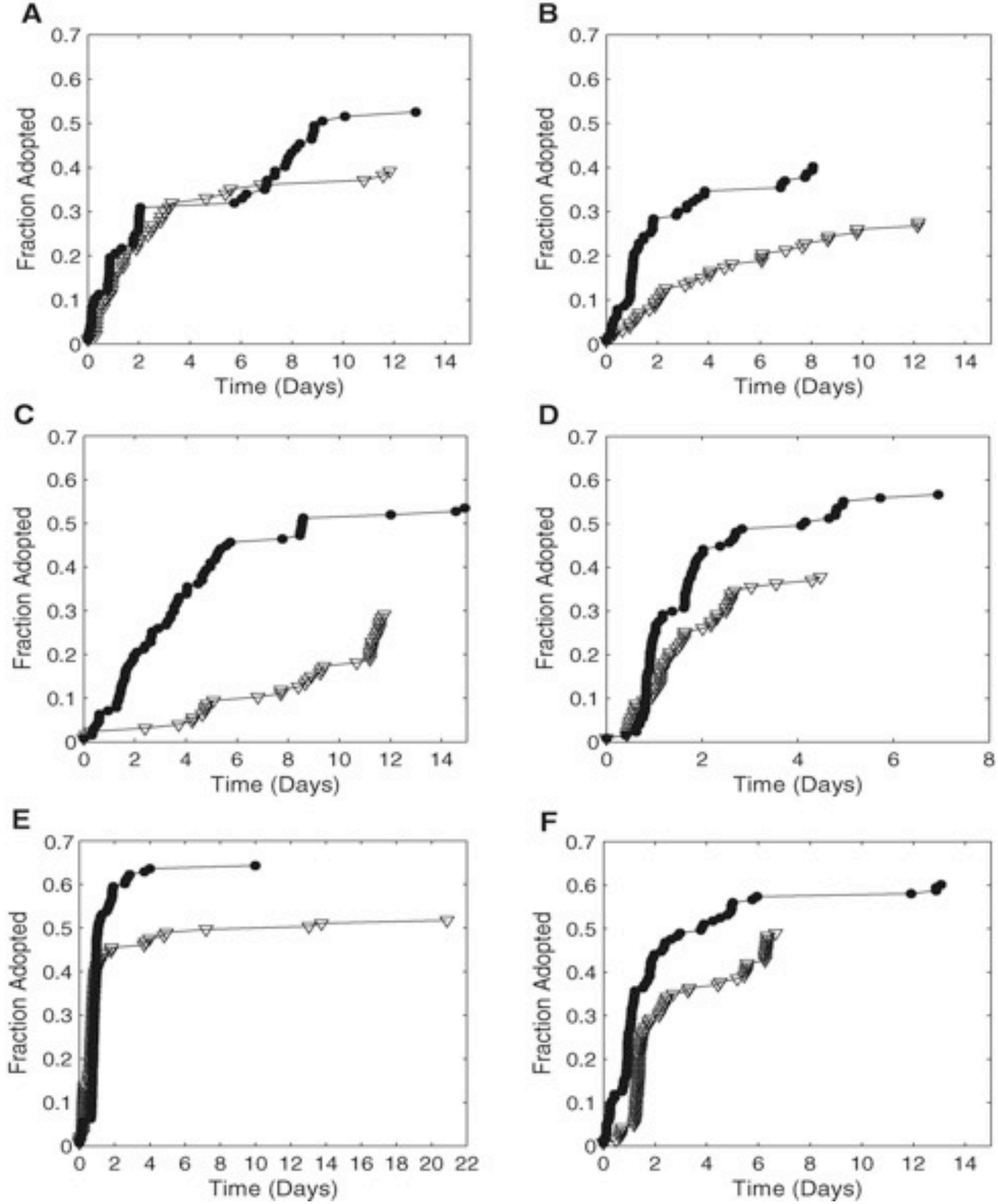
homophily
geographic proximity
interpersonal affect


Here's How it Works - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://healthylifestyle.rwj.harvard.edu/
Google
The Healthy Lifestyle Network
You are: John-672
Finish
Your health interests:
* Weight loss and dieting
* Lowering cholesterol
* Exercise programs
* Stress reduction and relaxation
These are your health buddies:
Toan-502
Health interests:
* Stress reduction and relaxation
* Exercise programs
* Alcohol use and stress factors
Jeff-459
Health interests:
* Exercise programs
* Stress reduction and relaxation
* Avoiding environmental pollutants
David-370
Health interests:
* Weight loss and dieting
* Exercise programs
* Using vitamin supplements
Joshua-150
Health interests:
* Stress reduction and relaxation
* Exercise programs
* Finding where and how to get screenings
* Limiting sun exposure
Jake-424
Health interests:
* Lowering cholesterol
* Stress reduction and relaxation
* Tobacco quitting and avoiding relapse
Jeremy-388
Health interests:
* Weight loss and dieting
* Lowering cholesterol
* Nutrition and meal planning
* Yoga and pilates
Done

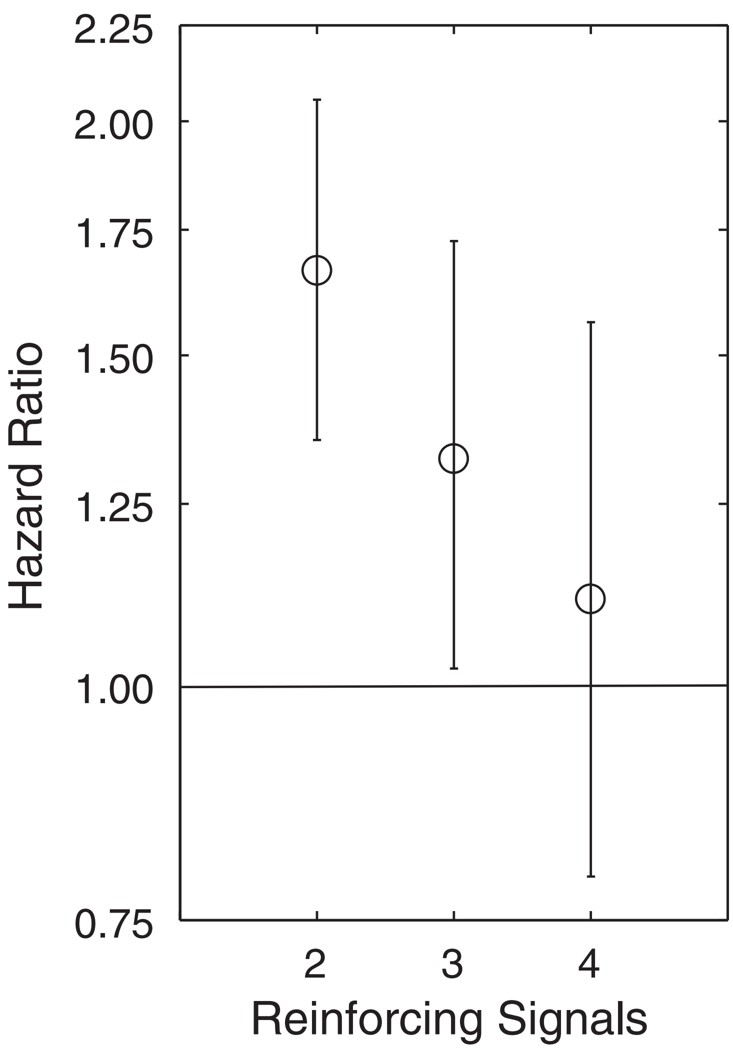
Adoption of behavior faster & stronger on lattice (circles) than on random network (triangles)

6 independent trials

note adoption:
- final fraction
- speed
- stochasticity

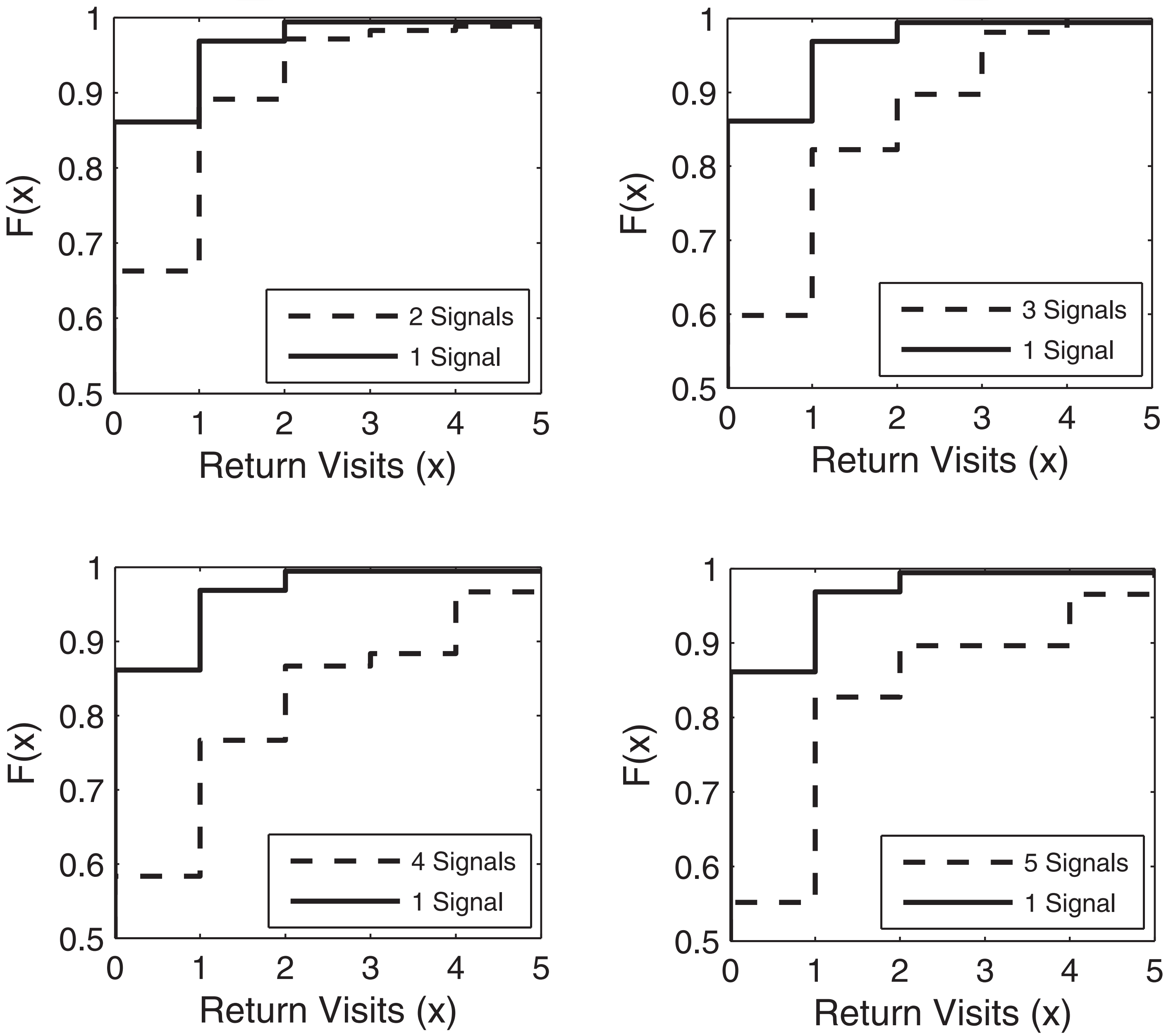


the effect of reinforcement



likelihood of adoption after n=2,3,4 social signals/likelihood of adoption after receiving 1 social signal

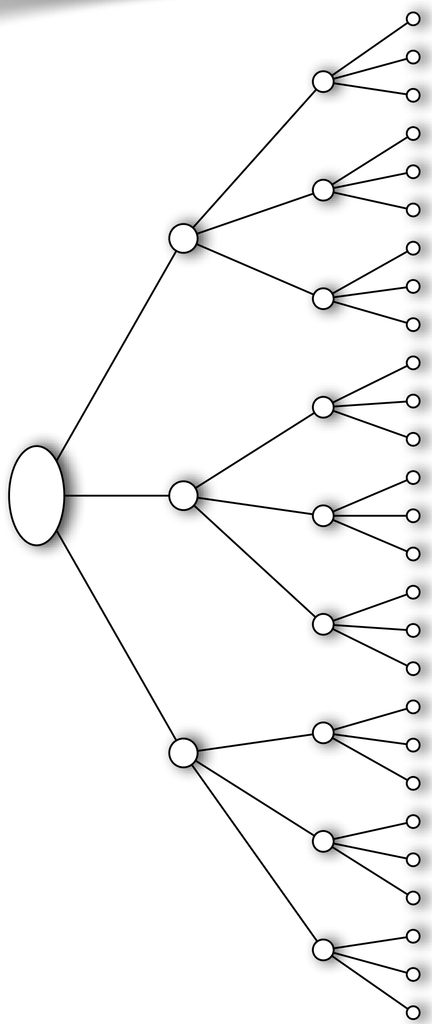
the effect of reinforcement 2

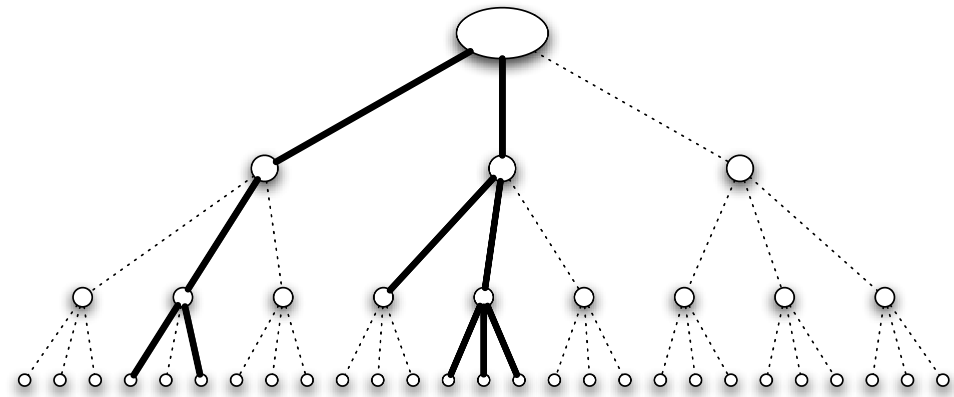


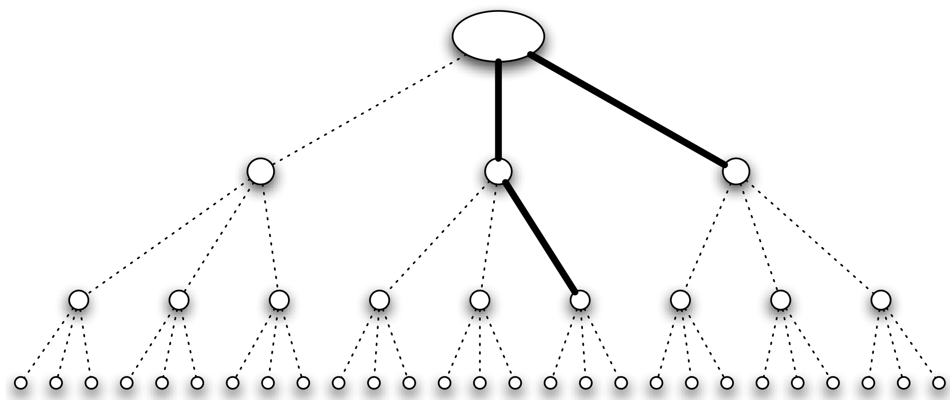
large-scale diffusion can reach more people and spread more quickly in clustered networks than in random networks

basic p,k model

- p prob of infection (here 1/3)
- k = fixed number of contacts (here 3)







R0 := p * k
R0 < 1 ?

Suppose X is a random variable on $\mathbb{N}$, its generating function is defined as $f_X(z) = \sum_n p(X = n)z^n$; for instance $f_{\delta_n} = z^n$.

The *Boolean distribution* $p(X = 0) = 1 - p$, $p(X = 1) = p$, has gf (generating function) $1 - p + zp$.

The *binomial distribution* $p(X = k) := \binom{n}{k} p^k (1-p)^{n-k}$, has gf $B(n,p)(z) = (1-p+zp)^n$.

This is the nth power of the Boolean gf as B is a sum of iid Booleans. So $E(X) = np$, $V(X) = n(n-1)p^2 + np - (np)^2 = np(1-p) < n/4$.

For a branching process with branching X, the extinction probability is a fixed point of f_X:

$$p_{ext} = \sum_n p(X = n) p_{ext}^n = f_X(p_{ext})$$

If we are branching with a sum of k iid Booleans

$$f_X(z) = (1 - p + pz)^k$$

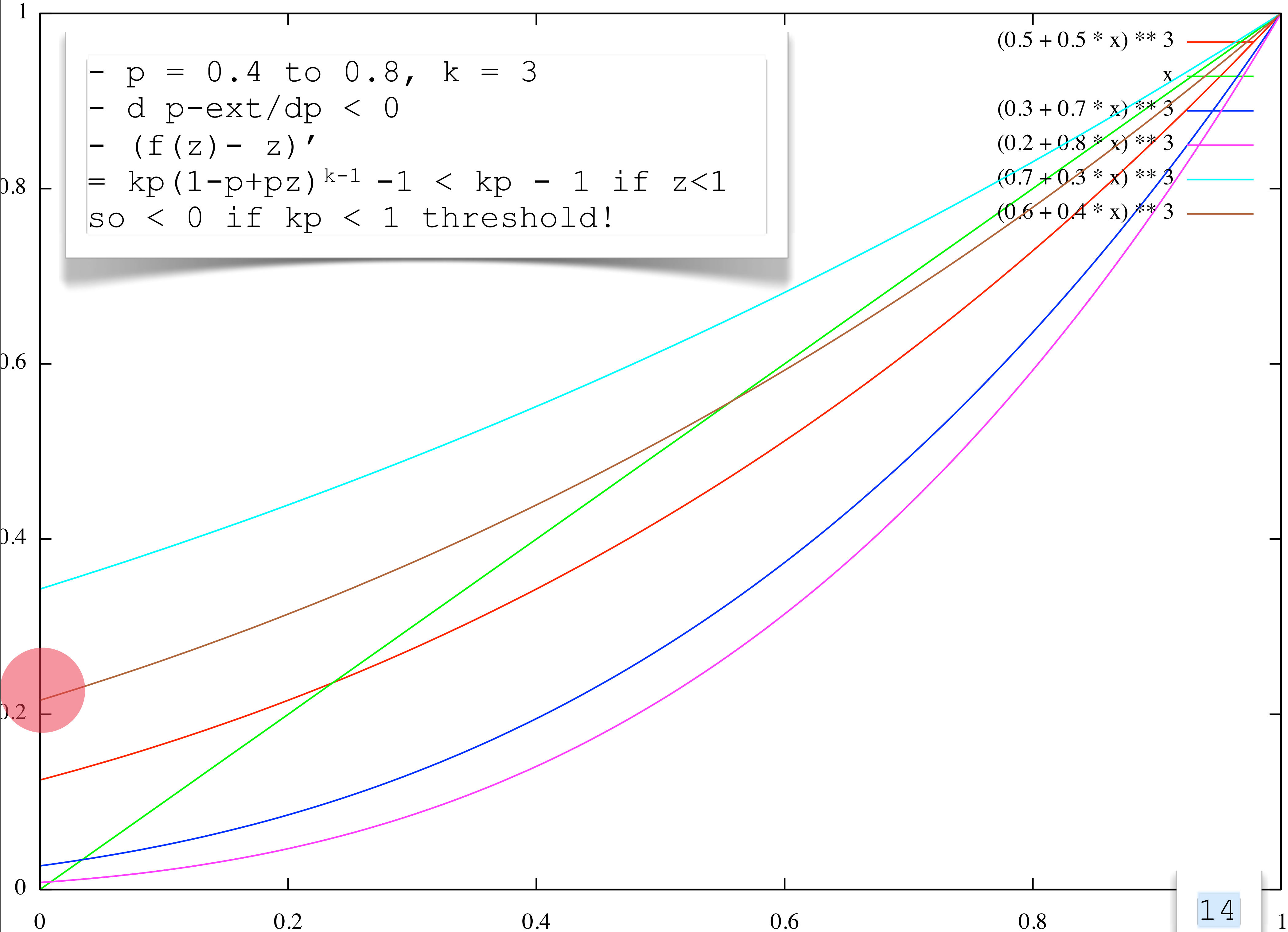
so to compute p_{ext} we need to examine:

$$z = (1 - p + pz)^k \quad \text{for } z \in [0, 1]$$

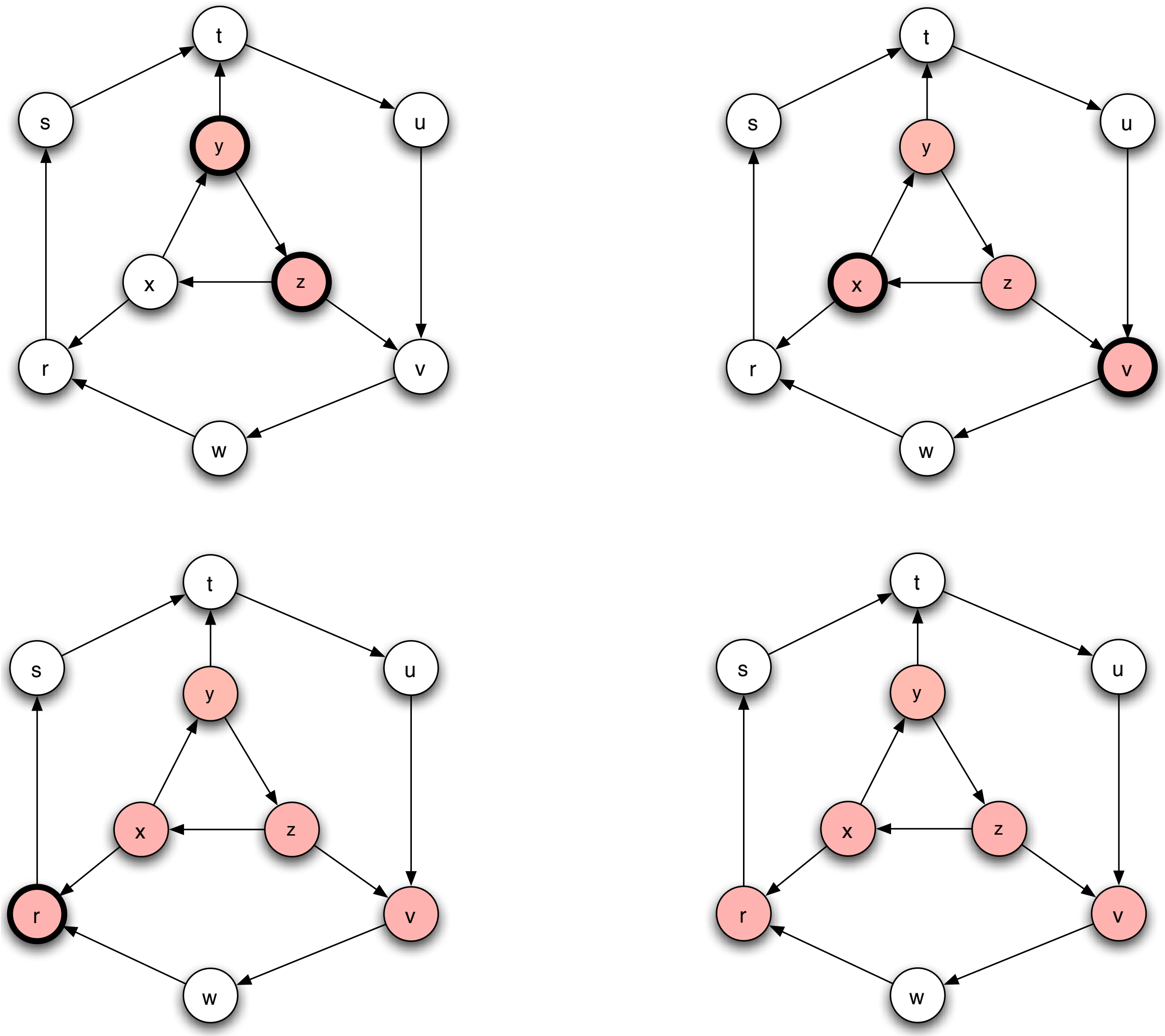
- p = 0.4 to 0.8, k = 3
- d p-ext/dp < 0
- (f(z)- z)'

= $kp(1-p+pz)^{k-1} - 1 < kp - 1$ if z<1

so < 0 if kp < 1 threshold!

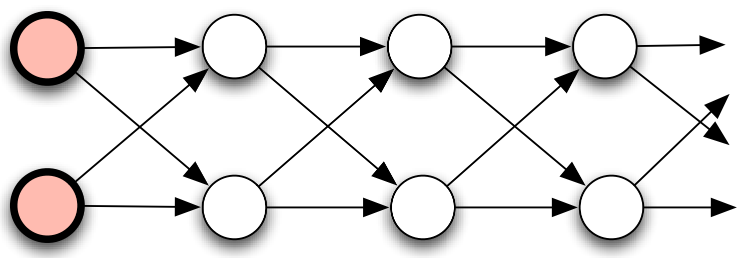


SIR model



- p prob of infection
- tI = infectivity duration (=1 here)

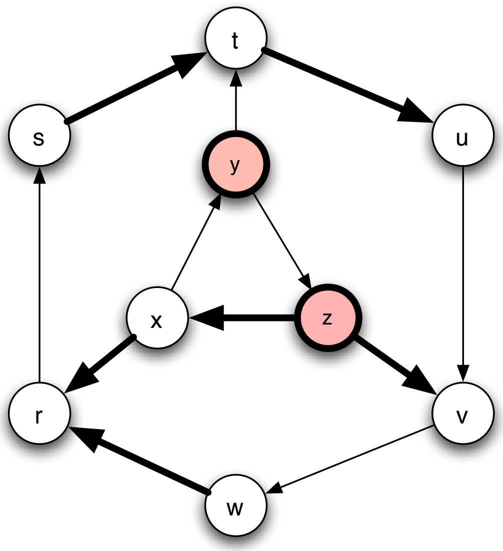
R0 is not enough anymore

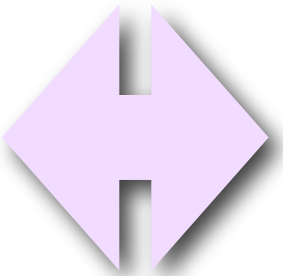


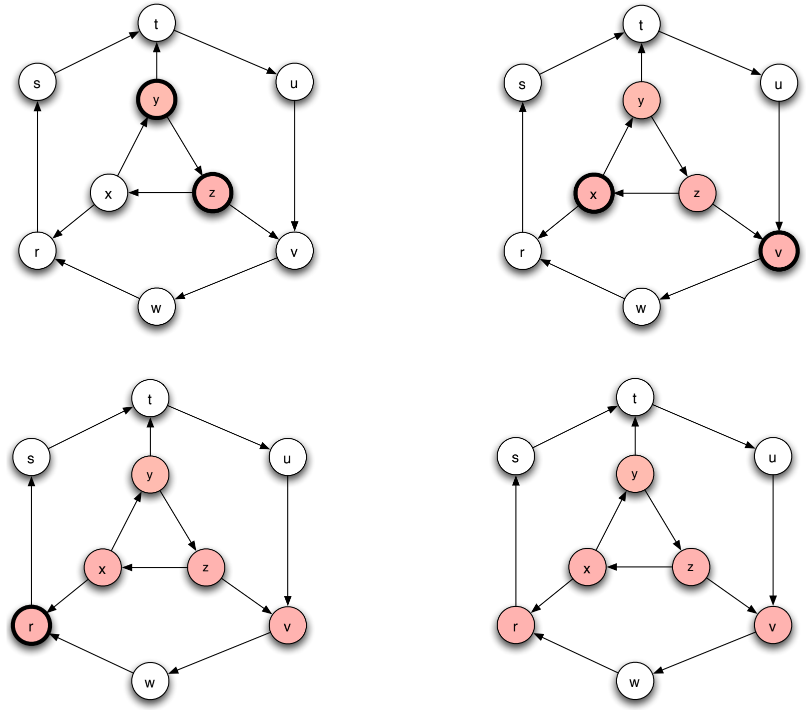
- p = 2/3
- tI = 1

p*k = R0 = 4/3 > 1

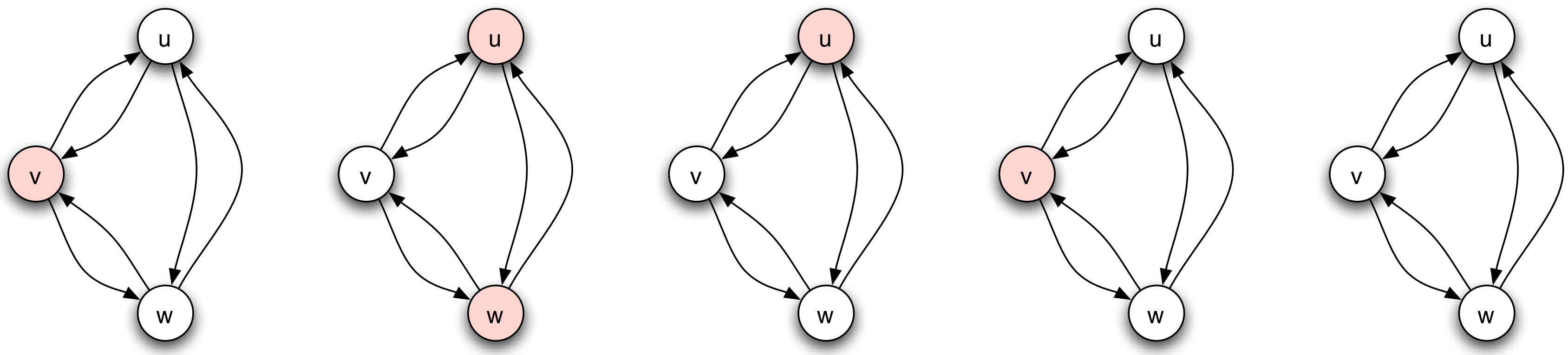
percolation
an equivalent static view

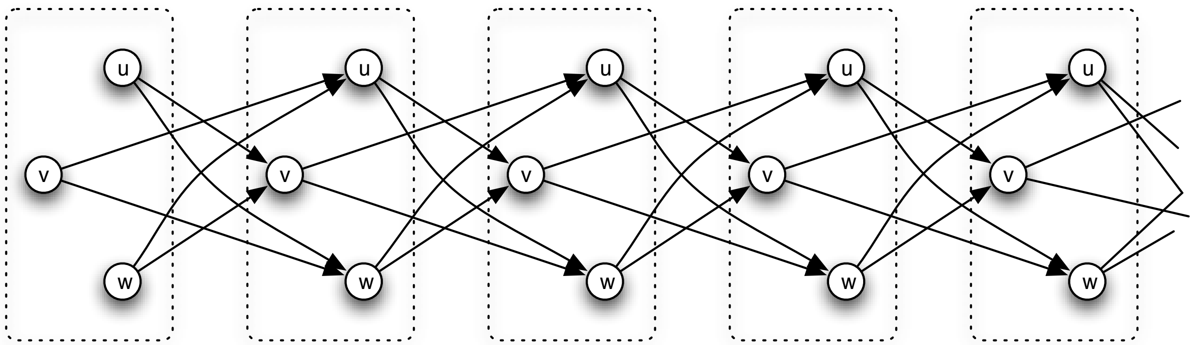


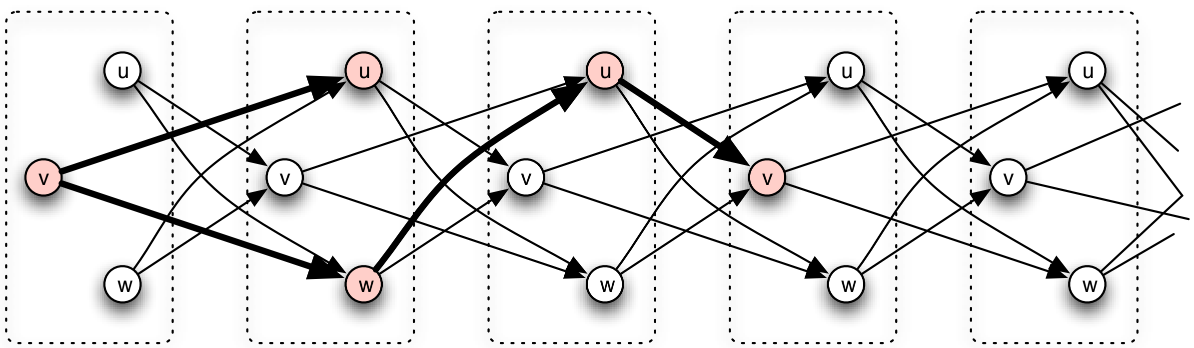




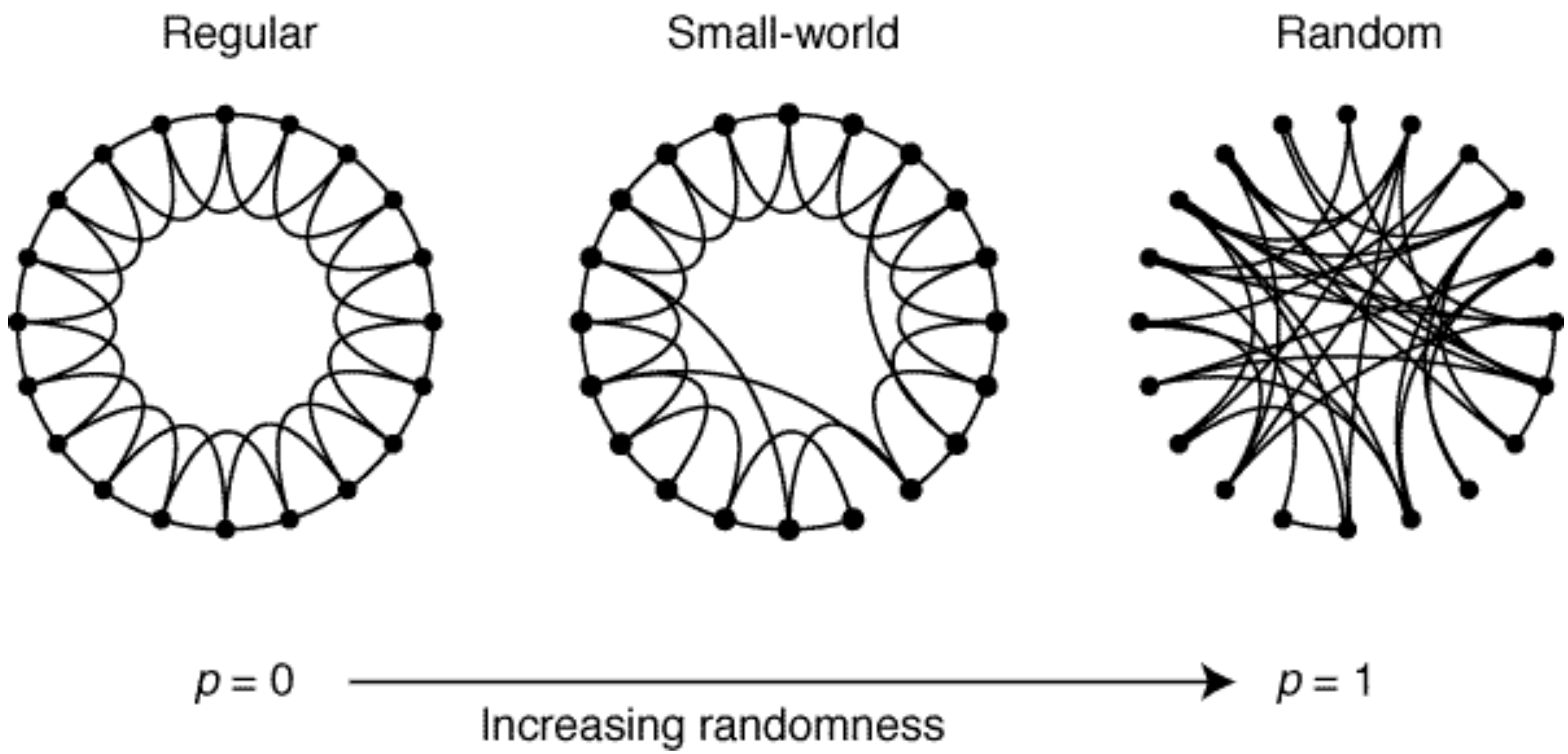
SIS model







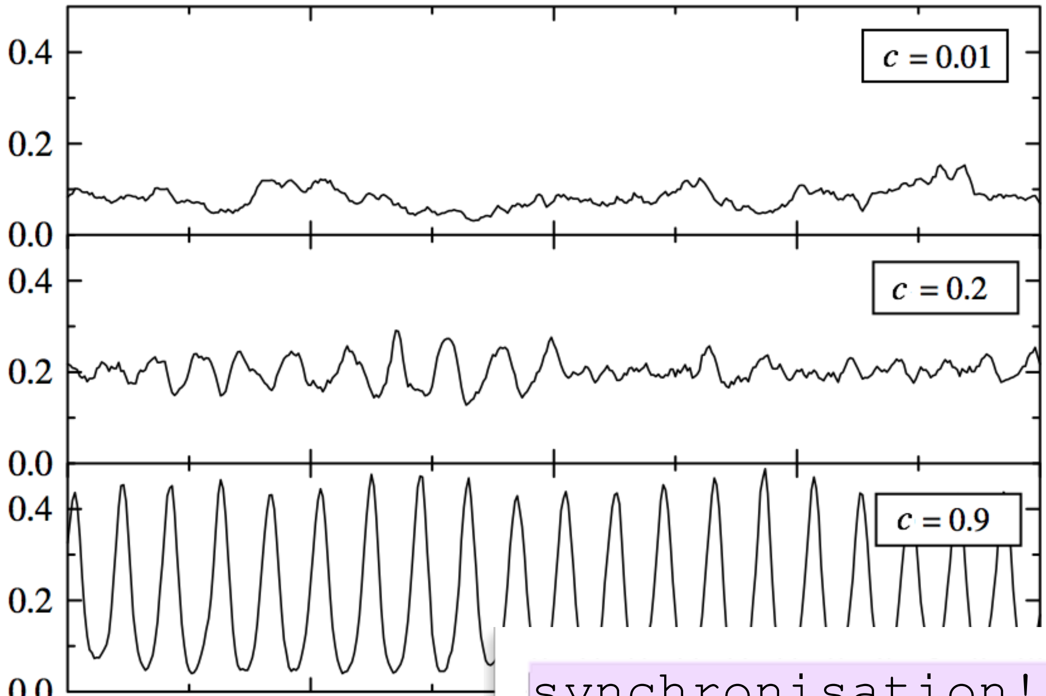
Watts-Strogatz "small-worlds"



SIRS model on a small world(c)

- p prob of infection
- tI = infectivity duration (=1 here)
- tR = immunity duration
- c = fraction of rewired local links (on a ring)

time vs fraction I/(S+I+R)



synchronisation!

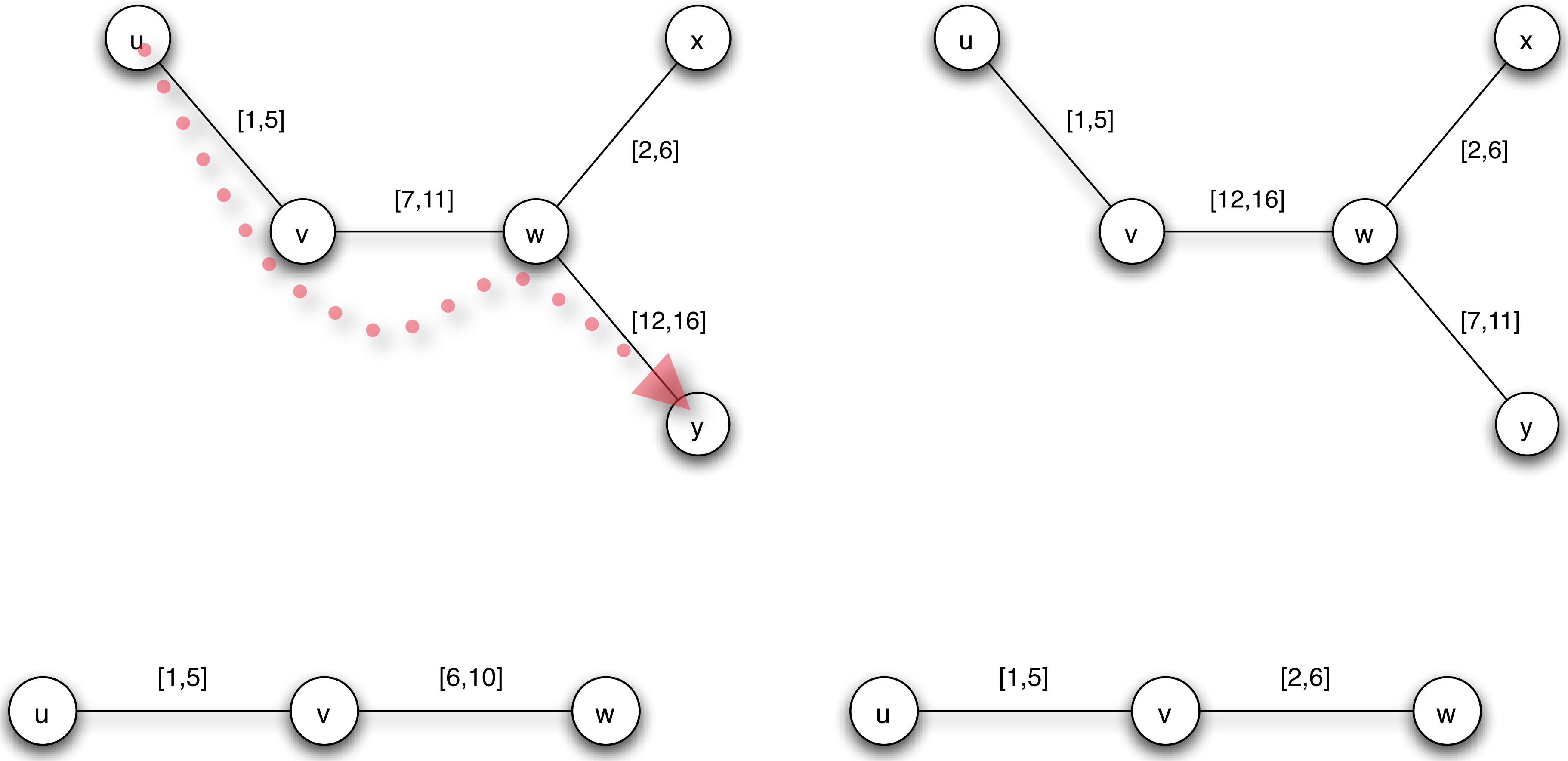
SIRS model II

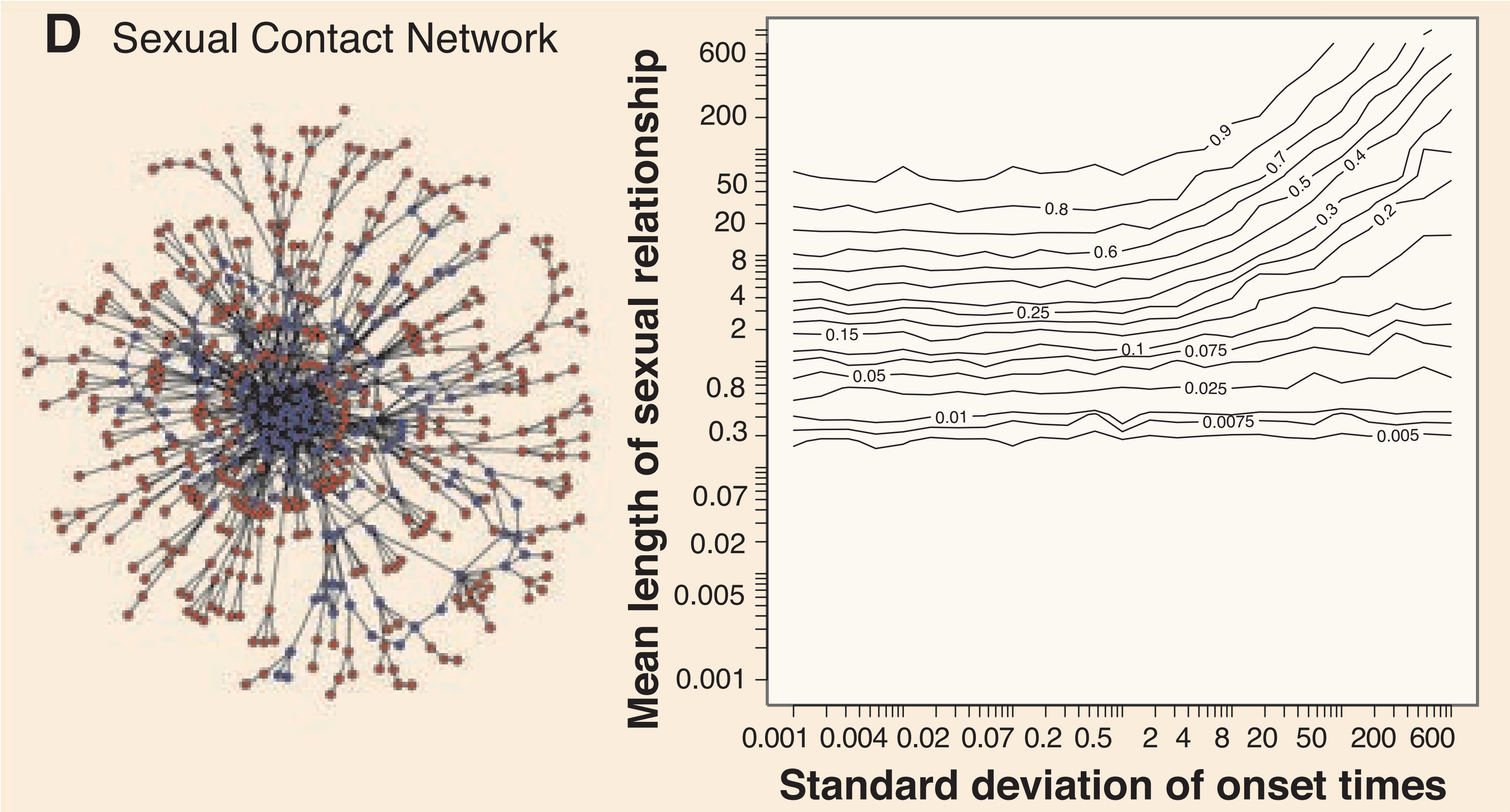
Rate of events in the SIRS model with demography

Event	Transition	Rate
Entry of S	X,Y,Z → X+1,Y,Z	μN
Infection	X,Y,Z → X-1,Y+1,Z	βyX
Death of S	X,Y,Z → X-1,Y,Z	μX
Loss of immunity	X,Y,Z → X+1,Y,Z-1	γZ
Recovery from I	X,Y,Z → X,Y-1,Z+1	νY
Death of I	X,Y,Z → X,Y-1,Z	μY
Death of R	X,Y,Z → X,Y,Z-1	μZ

www.nature.com/nature/journal/v433/n7024/full/nature03072.html

time-dependent & concurrent contact graph

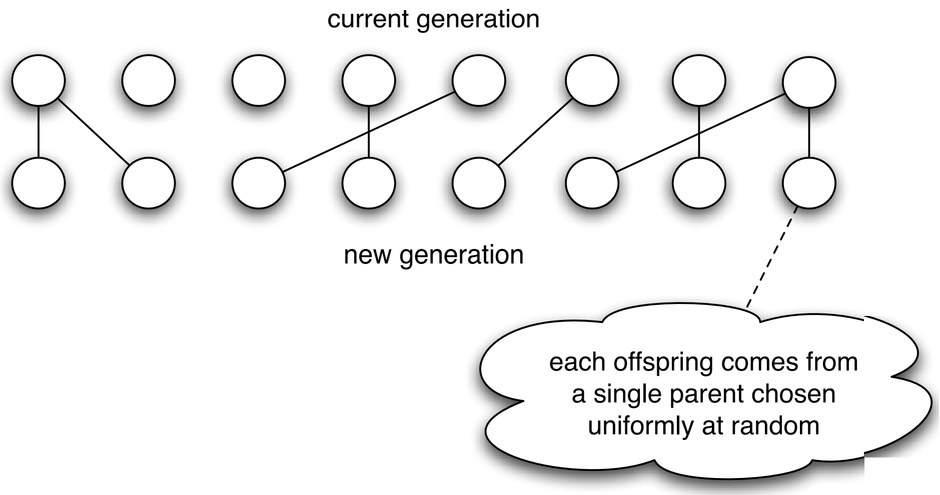


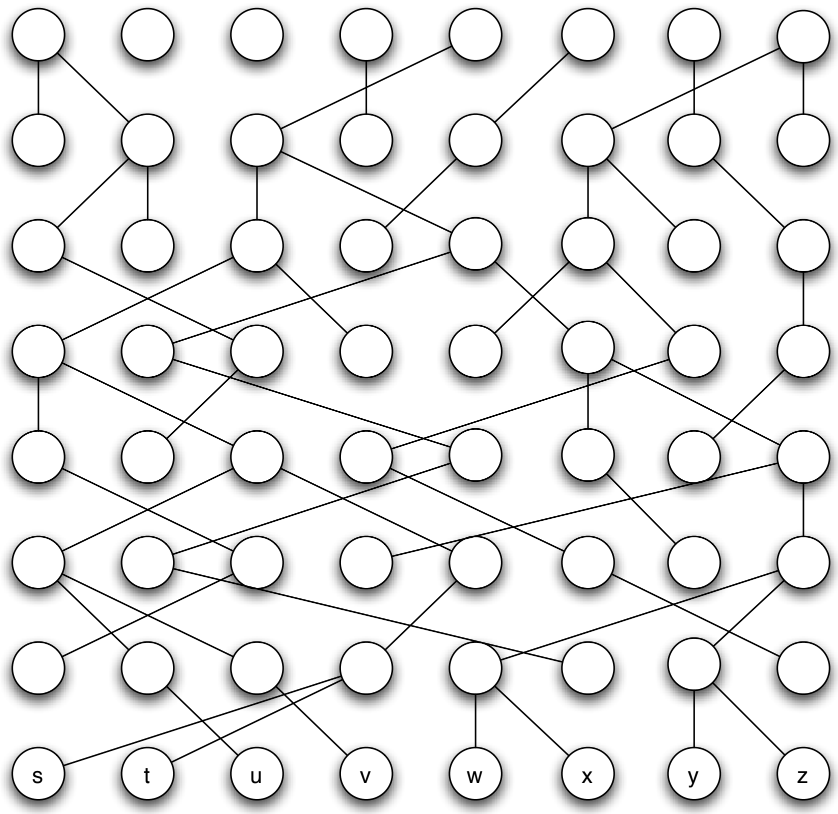


a time-aggregated network of sexual contacts not a good model
Butts. Revisiting the Foundations of Network Analysis. Science (2009) vol. 325 (5939) pp. 414-416

everyone may become infected or no one may be infected, depending on:
- edge duration
- deviation on time of onset

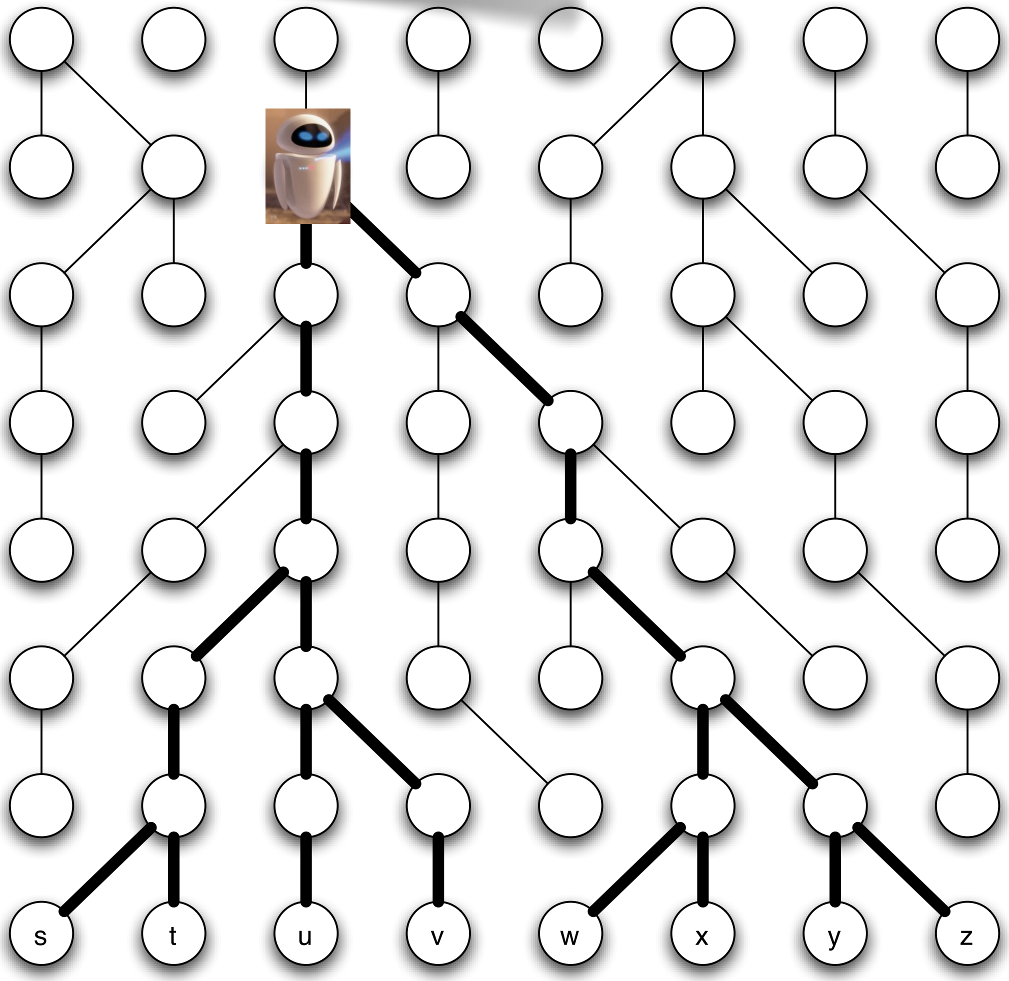
eve


current generation
new generation
each offspring comes from
a single parent chosen
uniformly at random


s
t
u
v
w
x
y
z

eve 2

most recent common ancestor



coalescence