

# Language Change and Social Networks

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# Outline

## ■ Background:

- Social networks in sociolinguistics and in computational modeling
- Recent developments in complex networks in general

## ■ A model of language change:

- Language change as a diffusion-through-learning process
- Effect of different types of social networks on the diffusion process.

## ■ Conclusions:

- Different structures of social networks show significantly different dynamics.

# Social Networks

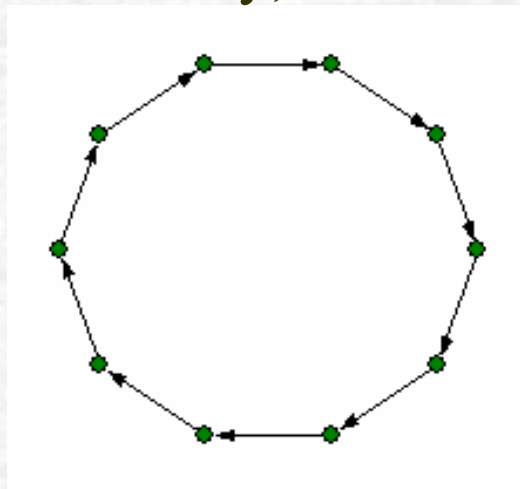
## ■ In sociolinguistics:

- Linguistic behaviors  $\leftrightarrow$  Social connections in the network  
More integrated in the network  $\rightarrow$  Higher tendency to use local variants
- Local & small size:  
e.g. Milroy (1980): <20 speakers; Eckert (1999): 69 speakers.
- Synchronic analyses, and individual oriented.

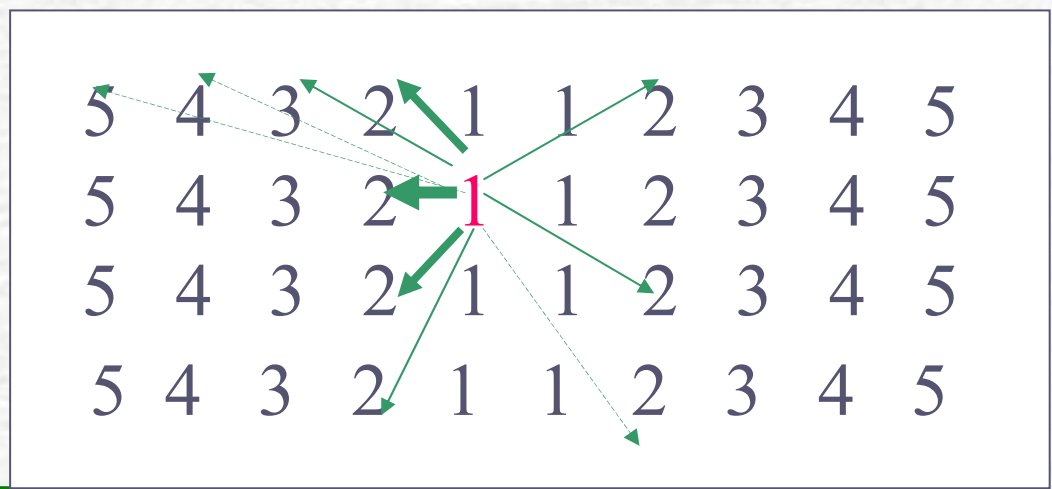
## ■ In computational modeling

- Random network (e.g. Batali, 1998); Regular network.

Kirby, 2000

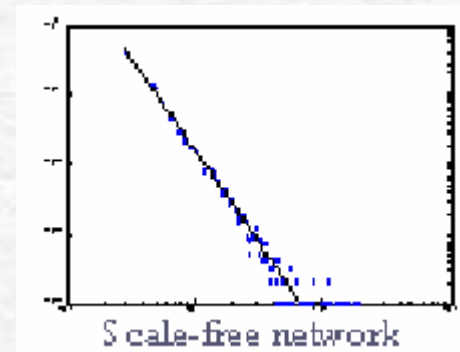
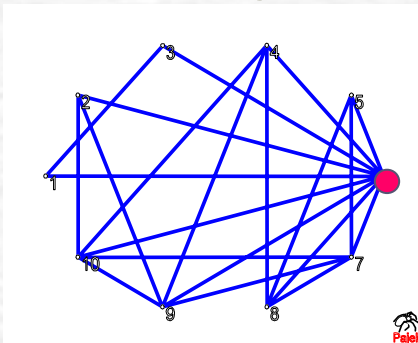


Nettle, 1999



## Recent development in complex networks

- Real-world networks (internet, collaboration network, etc.)
  - 1) Large-scale, but sparse
  - 2) Neither regular nor random
- Two new types of networks:
  - **Small-world network** (Watts & Strogatz, 1998)
    - Short distance between any two nodes (like random network)
    - High clustering coefficient (like regular network)
  - **Scale-free network** (Barabási & Albert, 1999)
    - Some "hubs" connected to a large number of nodes
    - Power-law degree distribution



**Q: How would these different topologies of social networks affect language change?**

# Modeling language change

- **Language change: an innovation diffusion process.**

An innovative “changed form”  $c$  appears in  $I$  (number of innovators) agents, while all other agents use an “unchanged form”  $u$ . Form  $c$  will diffuse if learned by new agents subsequently.

“**Threshold problem**” (Nettle, 1999): if children learn from the majority, how can the innovation starting as a minority can be learned and spread?

Mainly two mechanisms to overcome the threshold:

- 1) **Functional selection: functional bias for the changed form:**  $\beta = f_c/f_u \geq 1$

- 2) Social selection

- **Aim: to examine the effect of different types of social networks in the diffusion process.**

Modified from Nettle (1999):

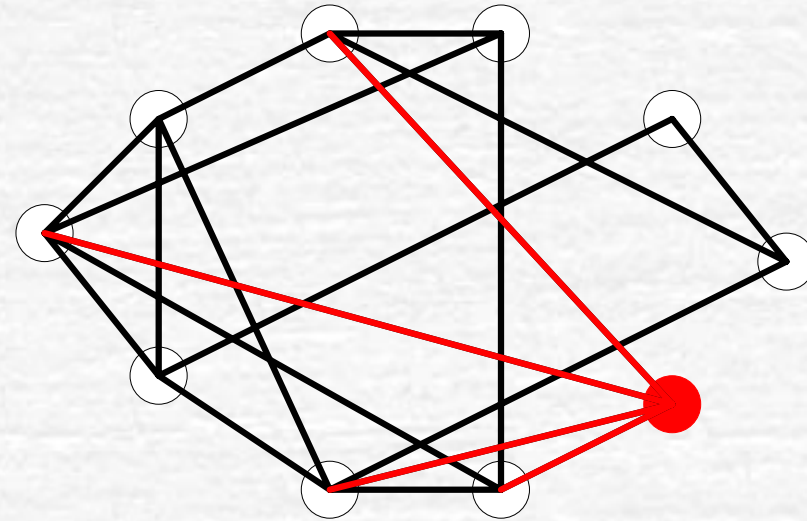
- Network structure: N nodes, four types
- Age structure: adult/learner = 3:2

each node:

- one of the two states:  $S(L) = \{u, c\}$
  - one of the 5 age stages:  $\{1\ 2\ 3\ 4\ 5\}$
- 1: infants, learn only  
 2: children, learn and affect others  
 3-5: adults, affect others only

- Changing population:

Population is updated after every generation: all agents advance in age by one stage; adults at stage 5 are replaced with new infants at stage 1.



$$S(L) = \begin{cases} c & \text{Fit}(c) \geq \text{Fit}(u) \\ u & \text{Fit}(c) < \text{Fit}(u) \end{cases}$$

$$\text{Fit}(u) = f_u \sum_{i=1}^U S(i) \quad \text{Fit}(c) = f_c \sum_{i=1}^C S(i)$$

$U, C$ : frequency of  $u$  and  $c$

$f_u, f_c$ : the functional value of  $u$  and  $c$

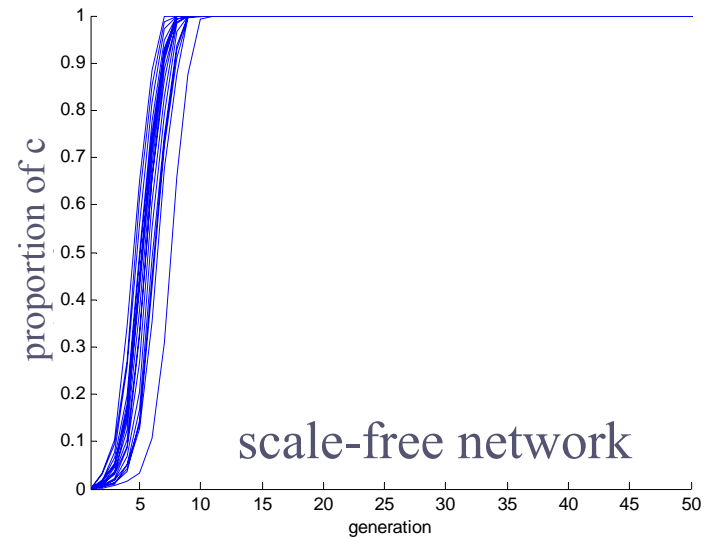
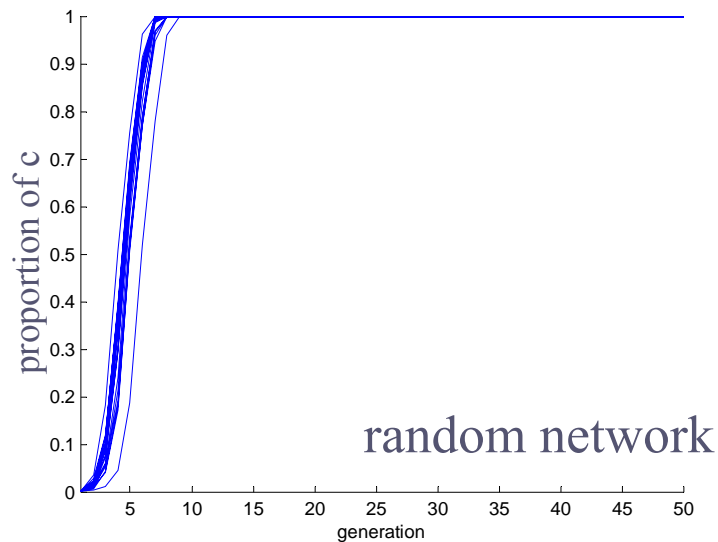
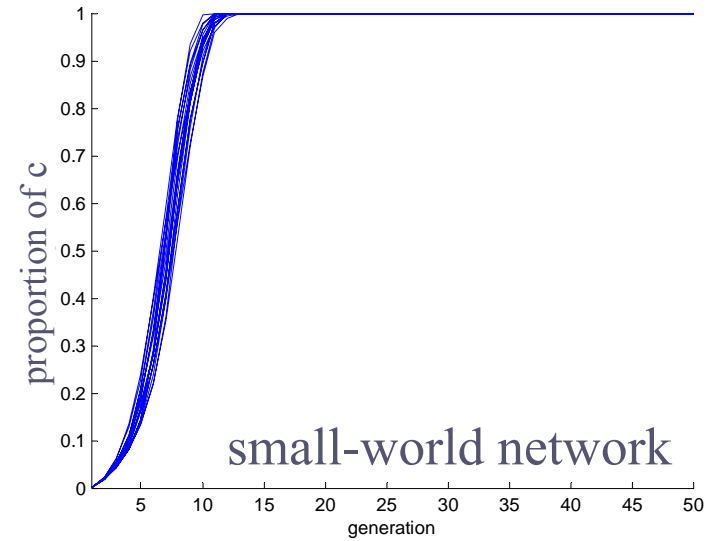
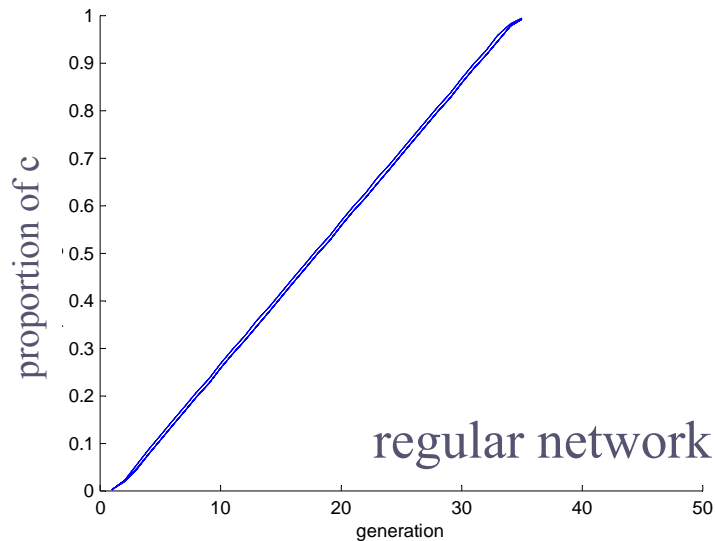
$$U=3, C=1, \beta = f_c/f_u = 4/1$$

$$\text{Fit}(c) > \text{Fit}(u) \rightarrow S(L)=c$$



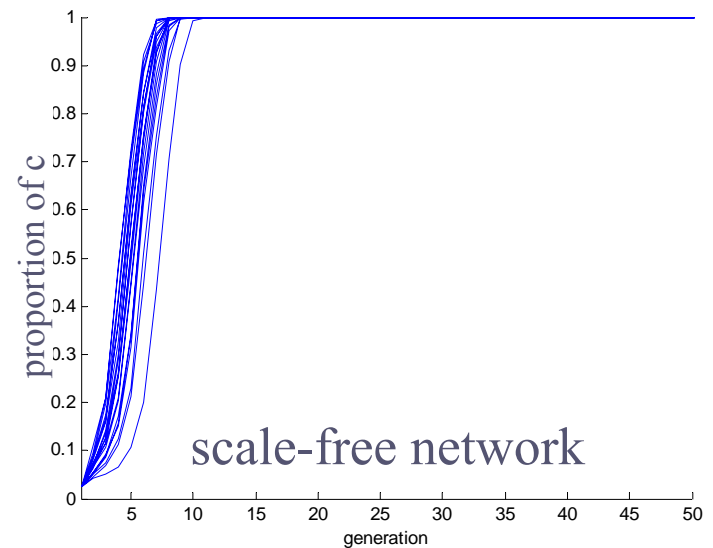
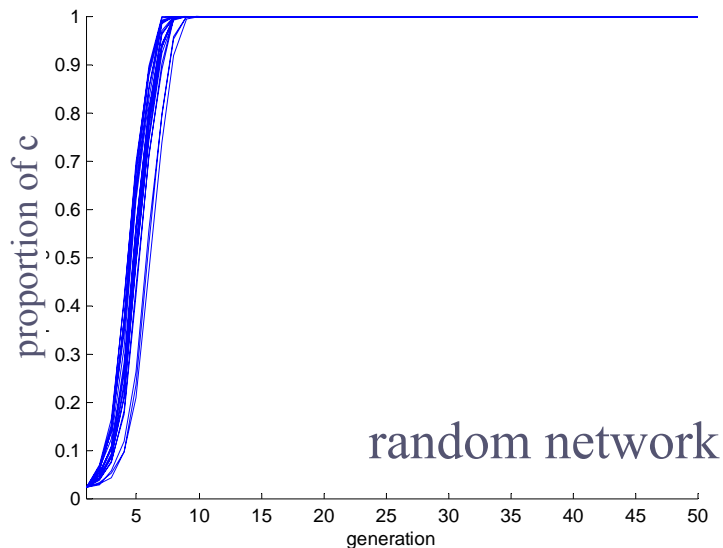
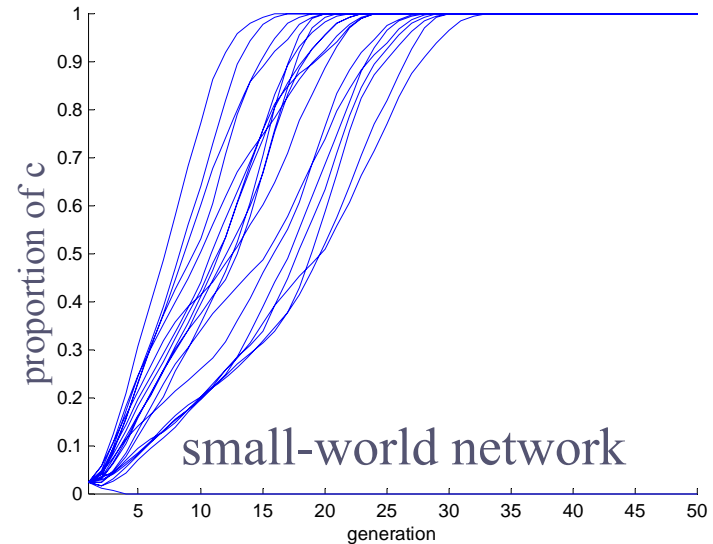
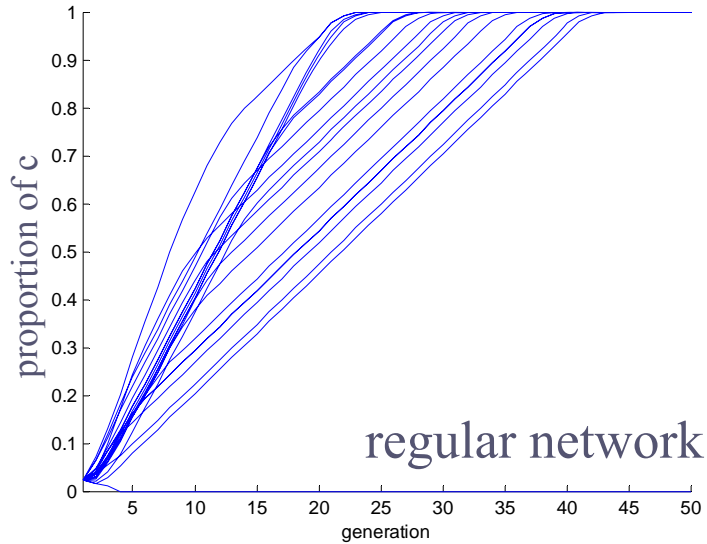
# Different network structures (I)

Condition 1:  $N=500$ ,  $\langle k \rangle = 20$ ,  $\beta = 20$ ,  $I = 1$ .

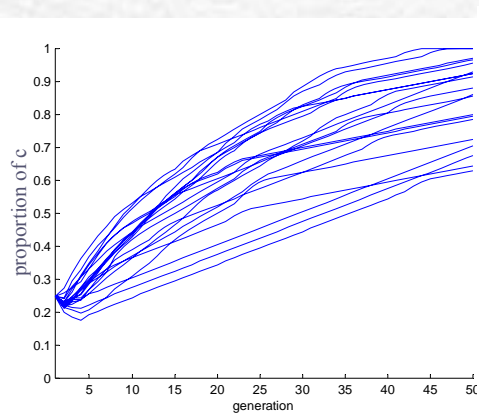


# Different network structures (II)

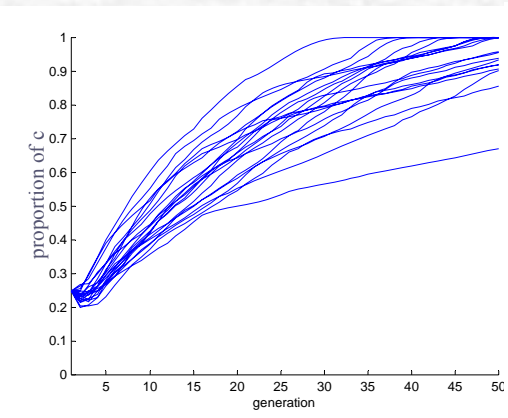
Condition 1:  $N=500$ ,  $\langle k \rangle = 20$ ,  $\beta = 10$ ,  $I = 10$ .



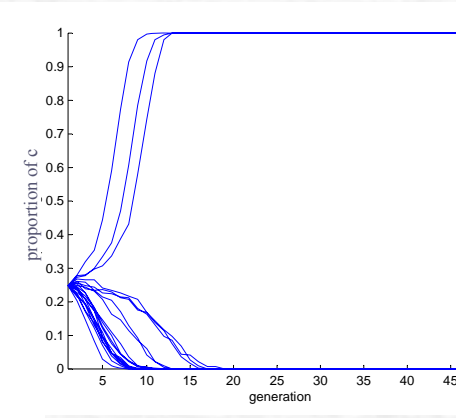
Condition 3:  $N=500$ ,  $\langle k \rangle = 20$ ,  $\beta = 2$ ,  $I = 100$



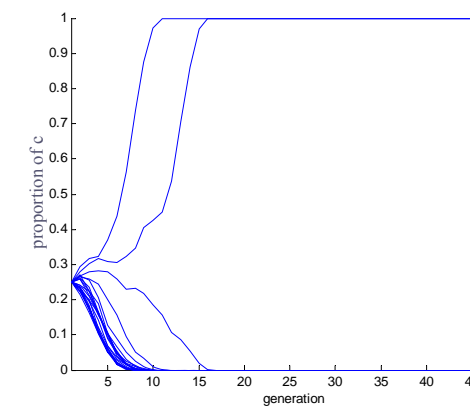
regular network



small-world network



random network



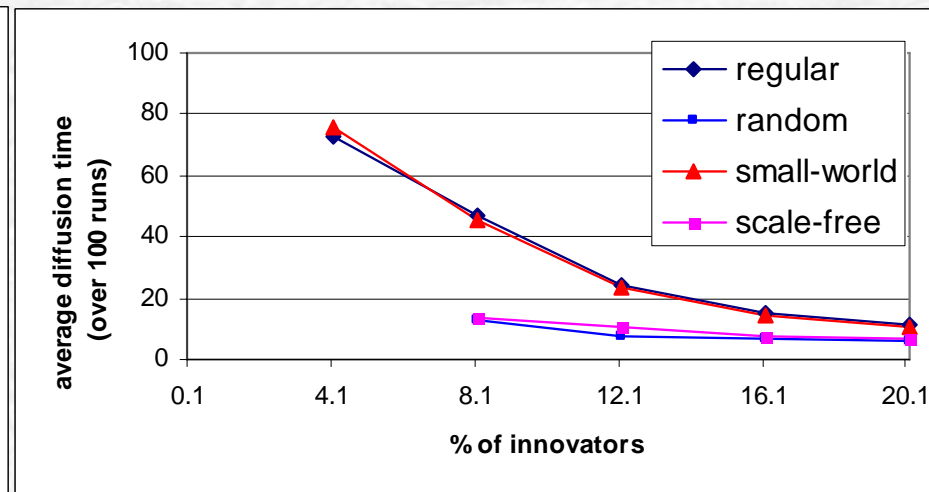
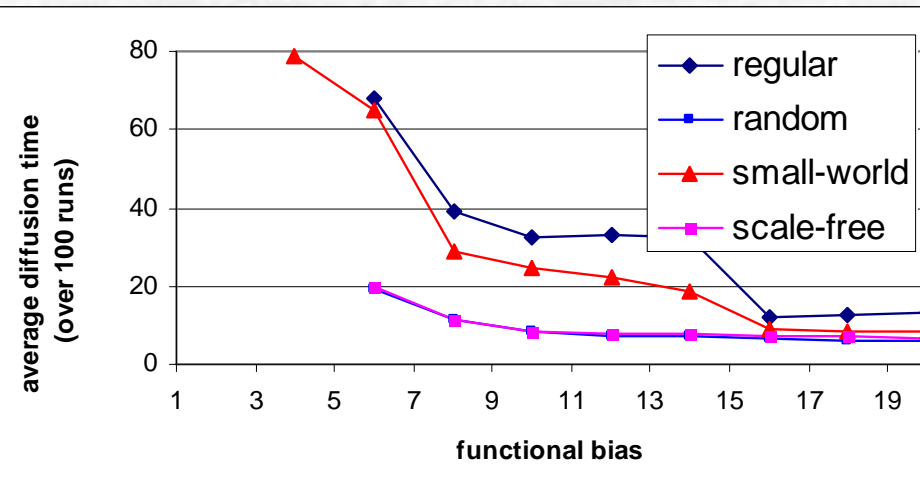
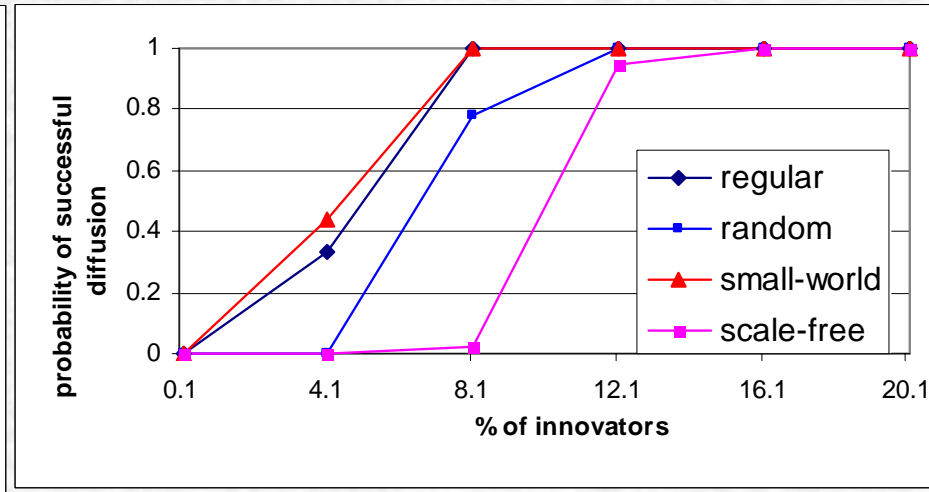
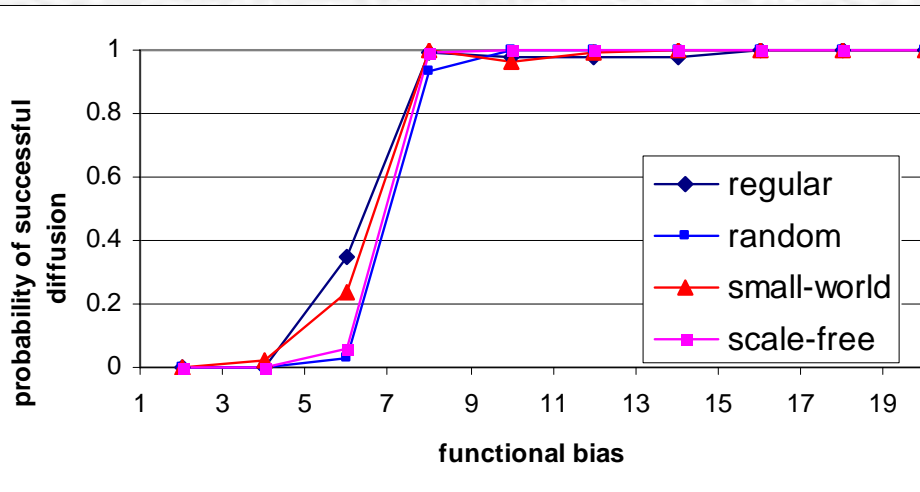
scale-free network

	Probability of success (successful runs/total runs)	Diffusion time (steps)
Regular network	20/20	102
Small-world network	20/20	80
Random network	3/20	10
Scale-free network	2/20	13

# Influences of functional bias and the number of innovators in different network structures

$I=10$

$\beta = 4$



- The dynamics in small-world network is similar to that in regular network: high probability of successful diffusion, but a slow diffusion rate.
- Scale-free network is similar to random network: fast diffusion rate, but a low probability of successful diffusion.

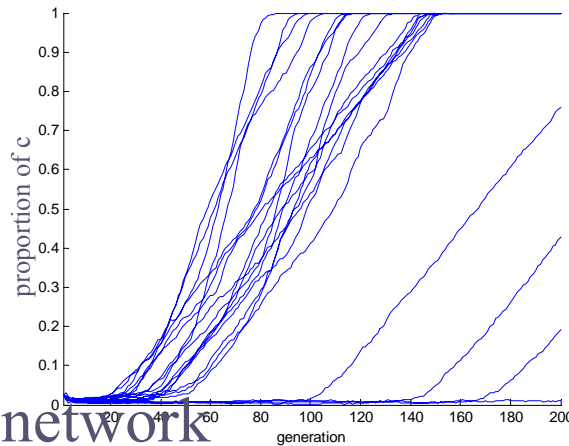
Small functional bias & small number of innovations	Probability of successful diffusion	Diffusion time
Regular network	High	Gradual diffusion
Small-world network		
Random network	Low	Abrupt diffusion
Scale-free network		

# Two types of learners

- **Categorical learner:** either  $u$  or  $c$
- **Probabilistic learner:** both  $u$  and  $c$ , with different probabilities. (e.g. “you” [nei] and [lei] in Cantonese; “neither” [ˈniːðə] and [ˈnaiðə] in English.)

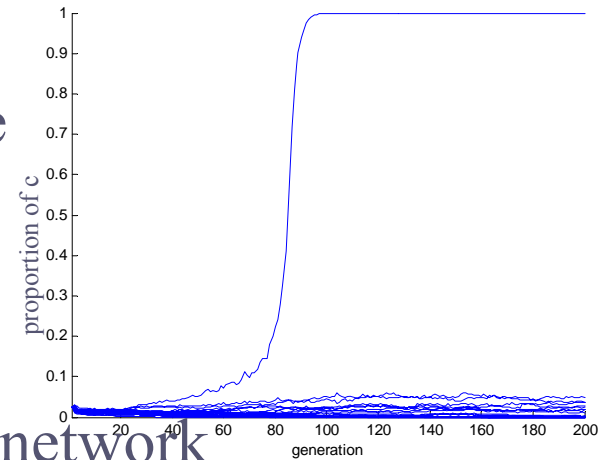
$\beta = 2, I = 1$

small-world network

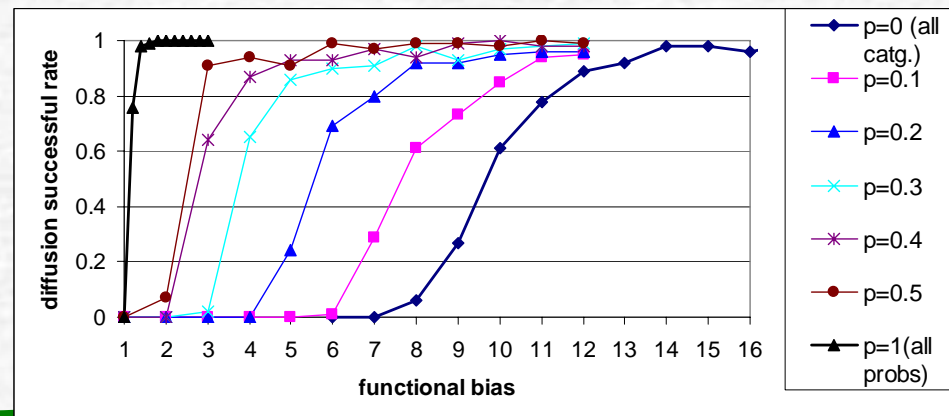
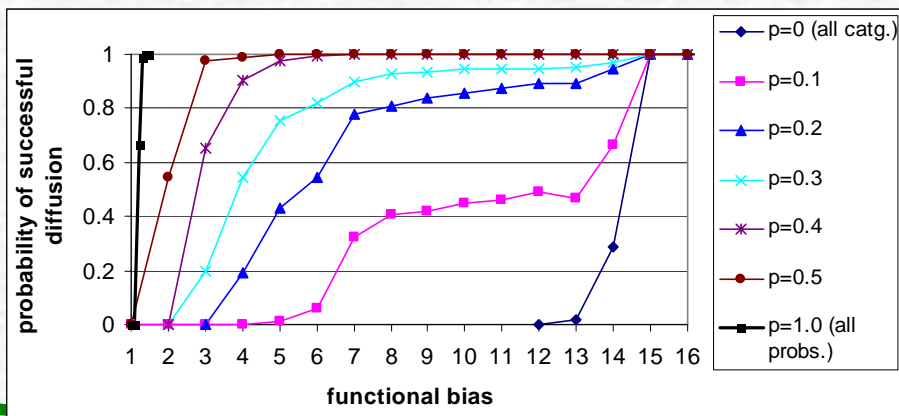


small-world network

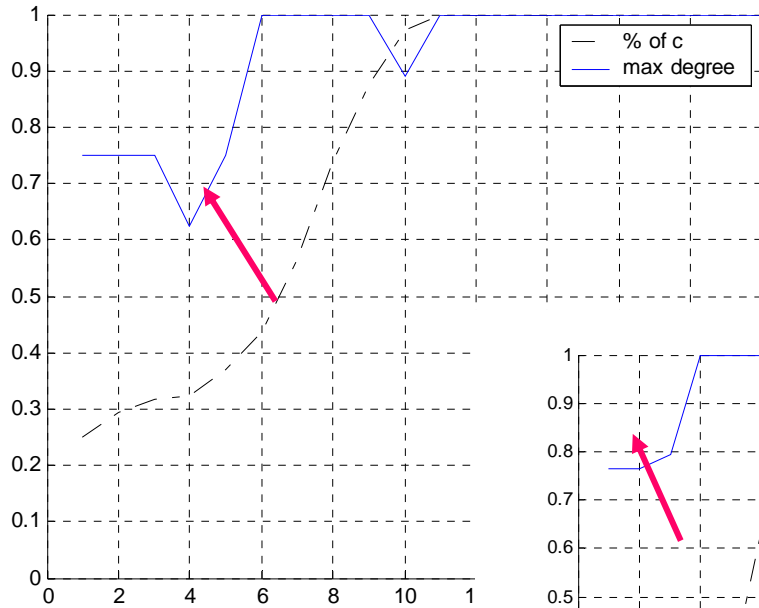
scale-free network



scale-free network

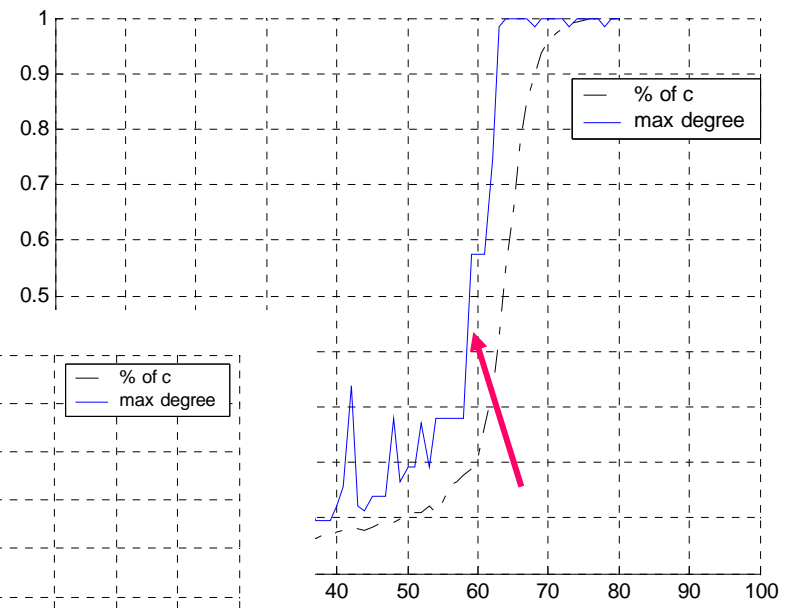


# Sharp S-curve diffusion pattern: the role of hubs in the networks



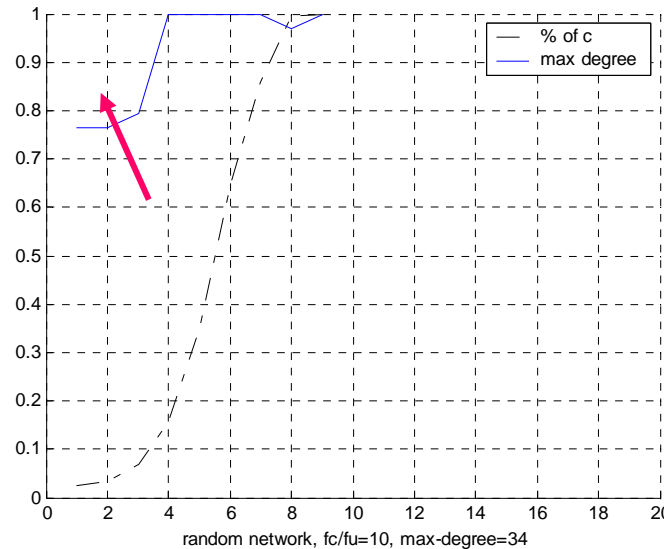
Scale-free network

100% categorical learners



e-free network

stochastic learners,  $\beta = 2, I = 10$

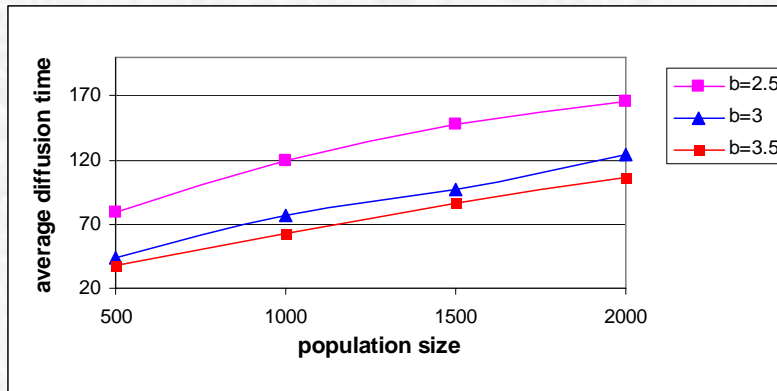


random network

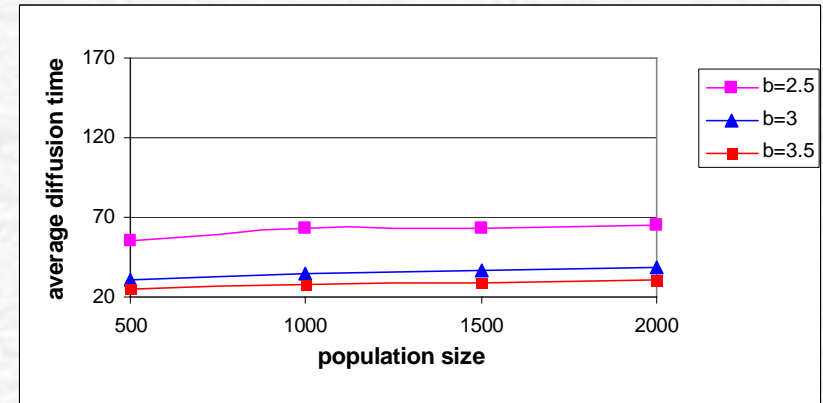
100% categorical learners,  $\beta = 10, I = 10$

# Different population sizes

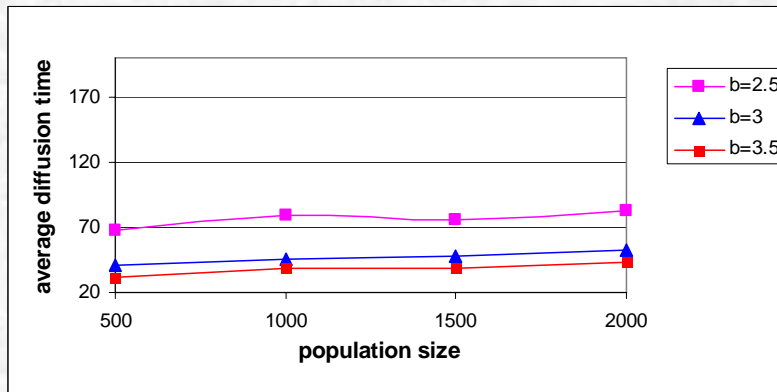
Q: larger size  $\rightarrow$  longer diffusion time, fewer changes? (yes--Nettle, 1999)



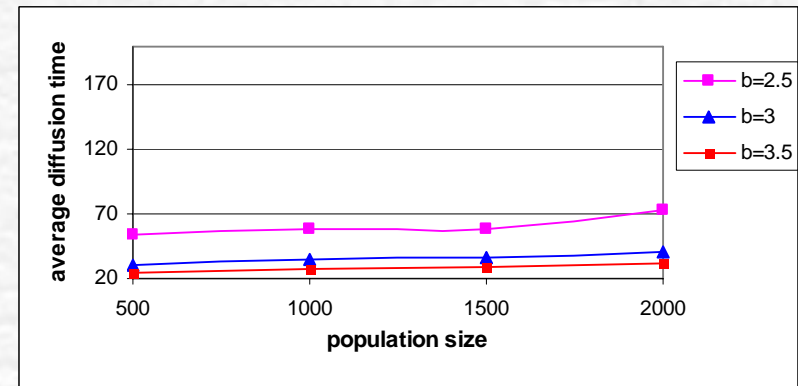
regular network



random network



small-world network



scale-free network



# Conclusion

*Different social structures have different features and different influences on language change:*

- Small-world behaves like regular networks, while scale-free networks are close to random networks.
- Small-world networks allow more changes, but each change proceeds at a much slower rate than scale-free networks, in which the diffusion always show a sharp S-curve pattern.
- The increase of population size does not affect the rate of innovation diffusion in small-world and scale-free networks.

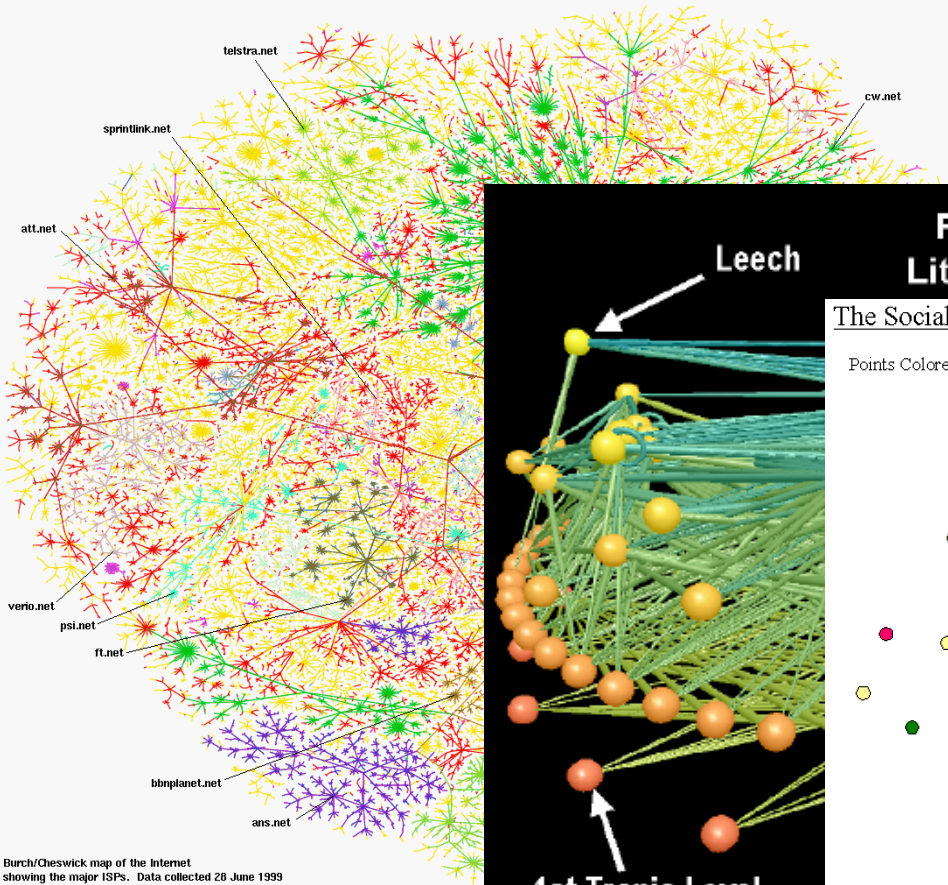
# *Acknowledgements*

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- ☺ This work is supported by City University of Hong Kong Grants No.9010001, 9040781.

Danke schön! - Thank you!

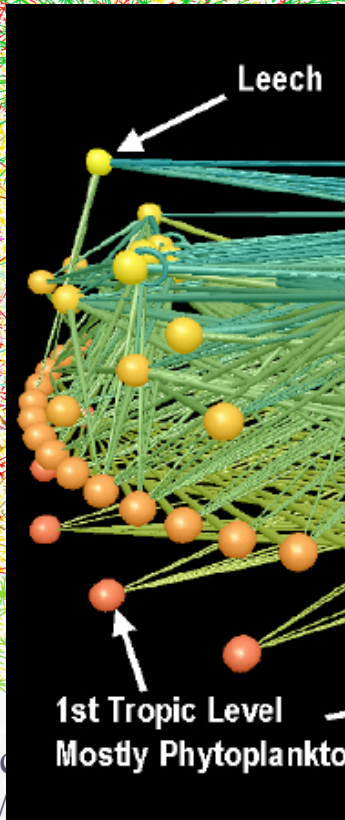
Comments are welcome

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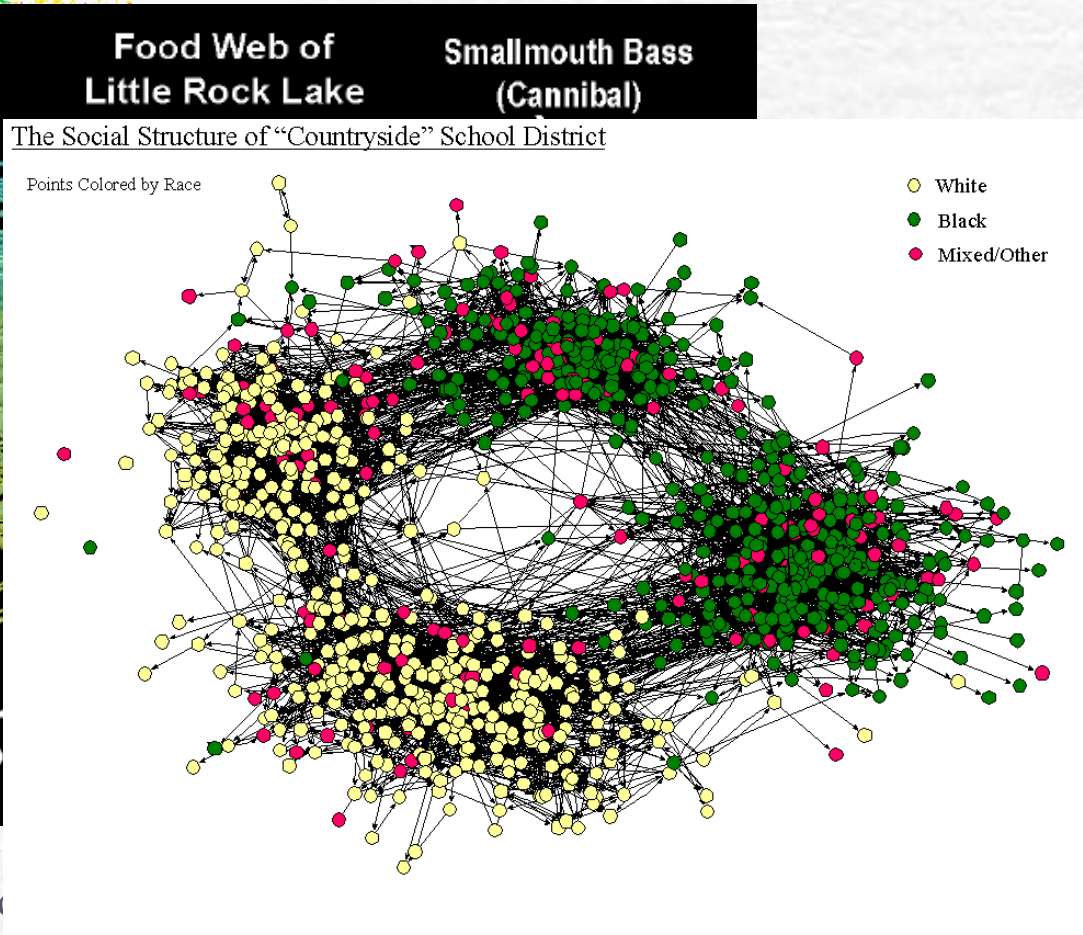


Burch/Ceswick map of the Internet showing the major ISPs. Data collected 28 June 1999

Map of Internet, 1999, Burch  
<http://research.lumeta.com/>

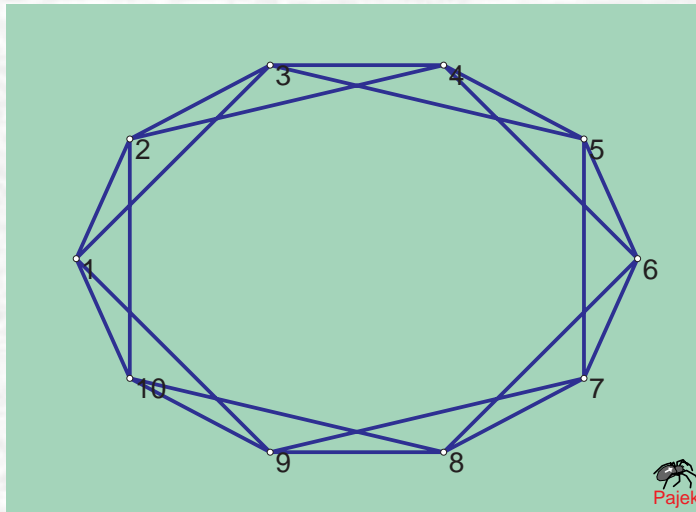


Foodwebs in Little  
<http://online.sfsu.edu>

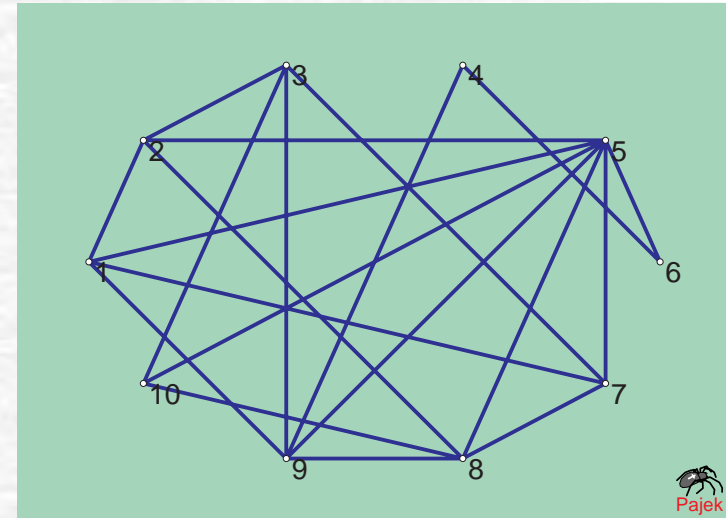


Friendship networks of countryside school district in Columbia, Moody, <http://www.sociology.ohio-state.edu/jwm/>

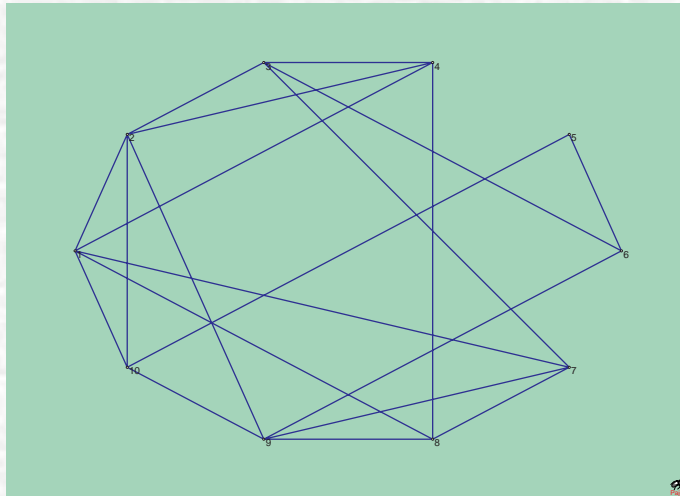
# Different types of networks



Regular Network



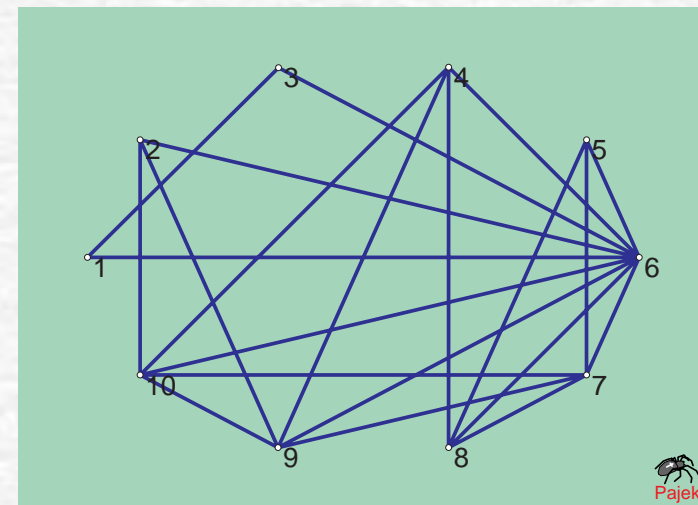
Random Network



Small-world Network

regular+ random rewiring

Watts & Strogatz (1998)



Scale-free Network

growing+ preferential attachment

Barabási & Albert (1999)

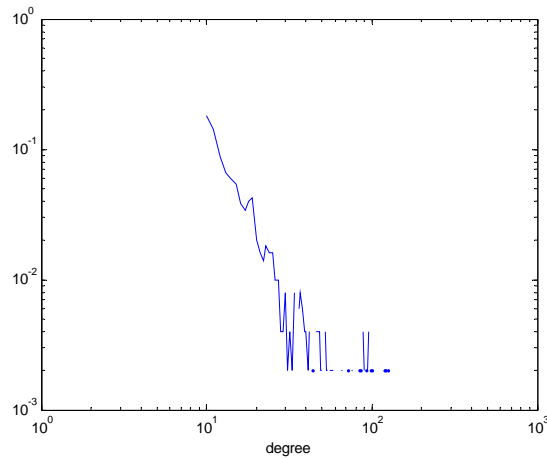
# Further questions/directions

- Can social structures in the real situations be divided into these two types: small-world and scale-free networks?
  - e.g. isolated villages vs. urban communities
- How would the dynamics of change differ in these different networks in the real world? Are there empirical data concerning the rate of change in different types of social structures?
- To simulate the effect of mass media on language change, where there are more unidirectional links.
- To model different contact situations: different proportions of groups, different degrees of social integration

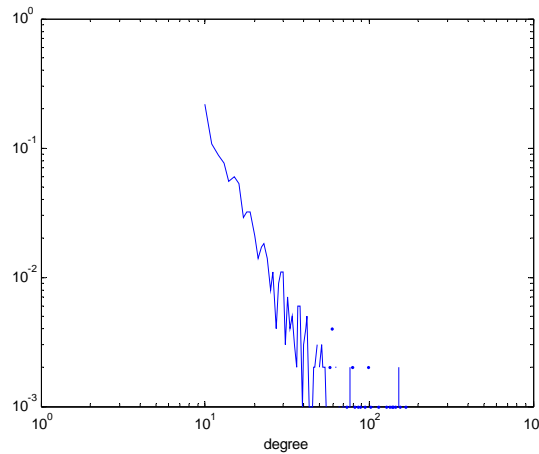
# Scale-free network

## ■ What is “scale-free”?

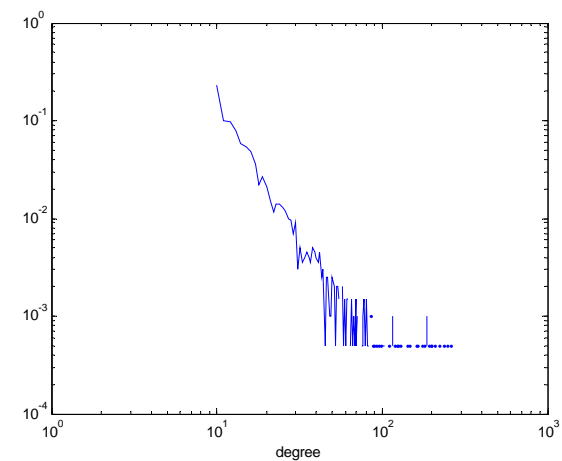
- Regardless of the network size, the degree distribution always show a similar power-law function.



N=500



N=1000



N=2000

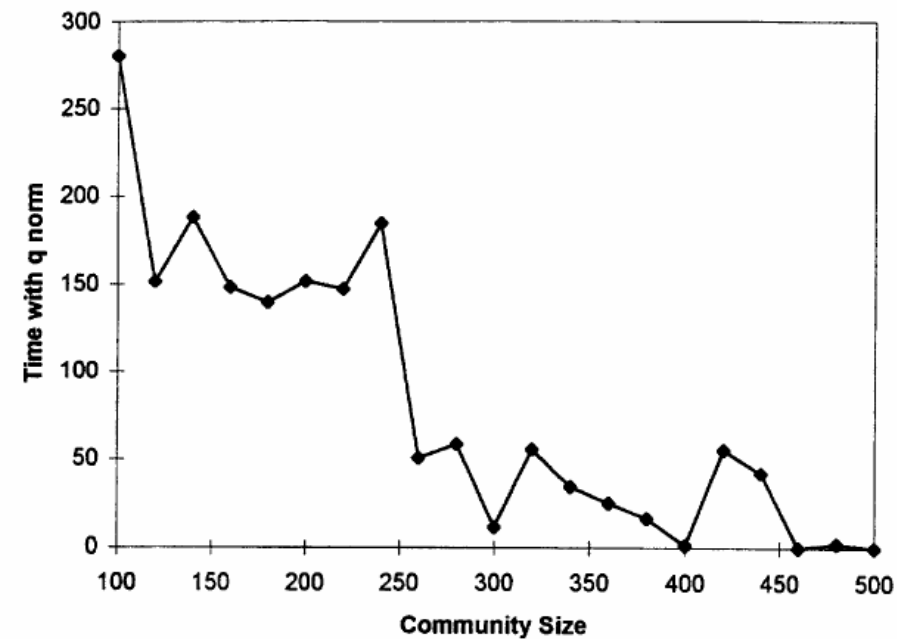


Fig. 5. The number of lifestages out of 1000 where  $q$  is the norm, with a small bias against  $q$  ( $b_q=0.8$ ), for different community sizes (results averaged over three sets of runs).

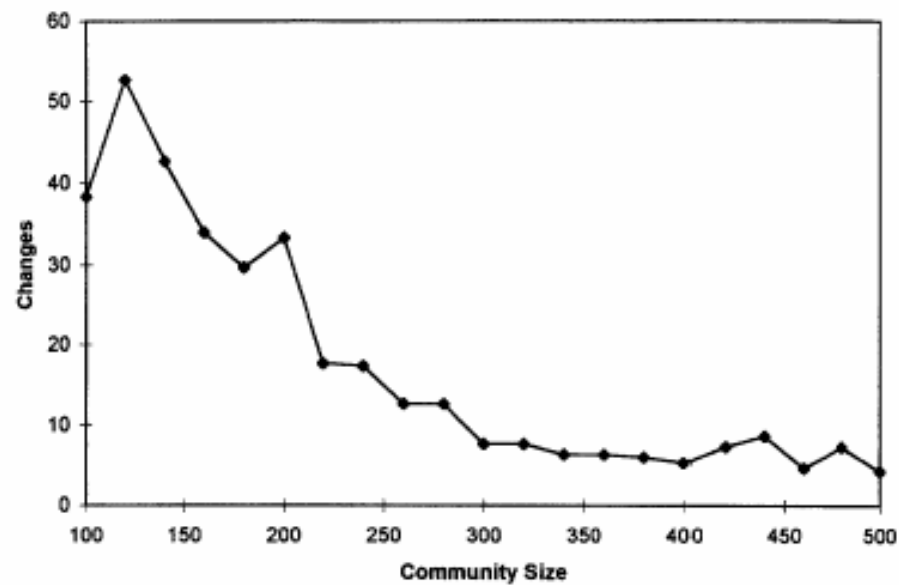


Fig. 2. The rate of change (number of changes of norm in 1000 lifestages) for runs of the simulation with different community sizes (results averaged over three sets of runs).

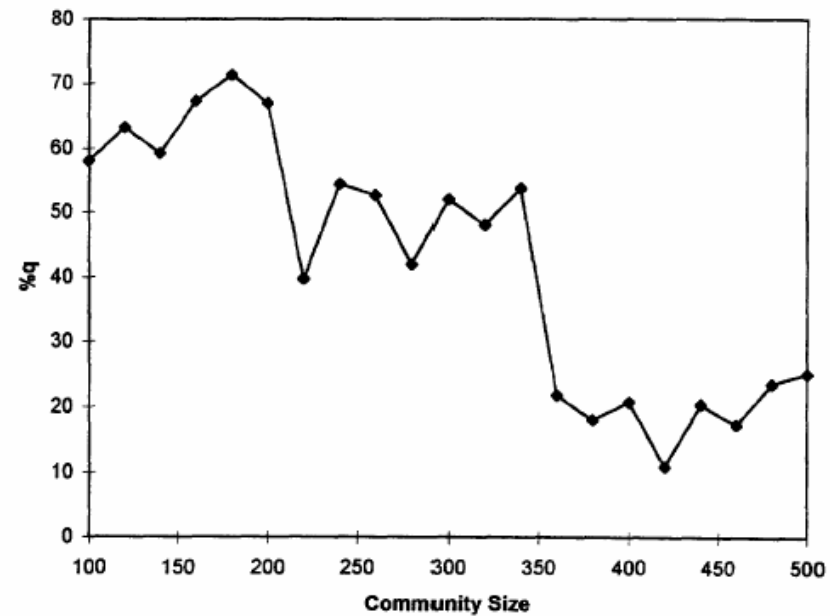


Fig. 3. The average percentage of the population with  $q$  20 lifestages after introducing 5 high status individuals using  $q$  into the community, for different community sizes (results averaged over 10 sets of runs).