# BIO 365 ecological networks

coordinators: Jordi Bascompte and Alessandro Vindigni

co-teachers: Klementyna Gawecka, Eva Knop, Fernando Pedraza, and Miguel Román

# Introduction to course

# outline of course

| From | To | | Thursday March 16 | Friday March 17 | Tuesday March 21 | Wednesday March 22 | Thursday March 23 | Friday March 24 | Tuesday March 28 | Wednesday March 29 | Thursday March 30 | Friday March 31 | Tuesday April 4 | Wednesday April 5 | Thursday April 6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10:15 | 12:00 | LECTURE | Outline and Intro | Food webs | | Mutualistic networks | Null models | Spatial networks | | Network robustness | Genetic networks | Evolution in networks | | Open time | Exam |
| | Speaker | LECTURE | Bascompte | Bascompte | | Bascompte | Bascompte | Gawecka | | Vindigni | Román | Pedraza | | | Vindigni |
| 12:00 | 13:00 | | Lunch | | Lunch | Lunch | Lunch | Lunch | Lunch | Lunch | Lunch | Lunch | | Lunch | Lunch |
| | Lead | EXERCISE | Vindigni | Vindigni | Knop | Gawecka | Pedraza | Gawecka | Vindigni/Pedraza | Vindingni | Román | Pedraza | | Instructors | |
| 13:00 | 17:00 | EXERCISE | Toolkit for network analysis | Measuring modularity | Sampling an ecological network | Measuring nestedness | Null models | Comparing networks in space | Simulating networks | Measuring network robustness | Analyzing genetic networks | Models of evolution in networks | Open time | General discussion | |

# general readings

# general readings


- Barabási, A.-L. (2002). Linked: The New Science of Networks. Perseus Books Group
- Bascompte, J. and Jordano, P. (2013). Mutualistic Networks. Princeton University Press
- Pascual, M. and Dunne, J.A. (2006). Ecological Networks: Linking Structure to Dynamics in Food Webs. Oxford University Press
- Pimm, S.L. (1982). Food Webs. Chicago University Press
- Several authors (2009). Complex Systems and Networks. (Special Section). *Science* 325: 405-432.

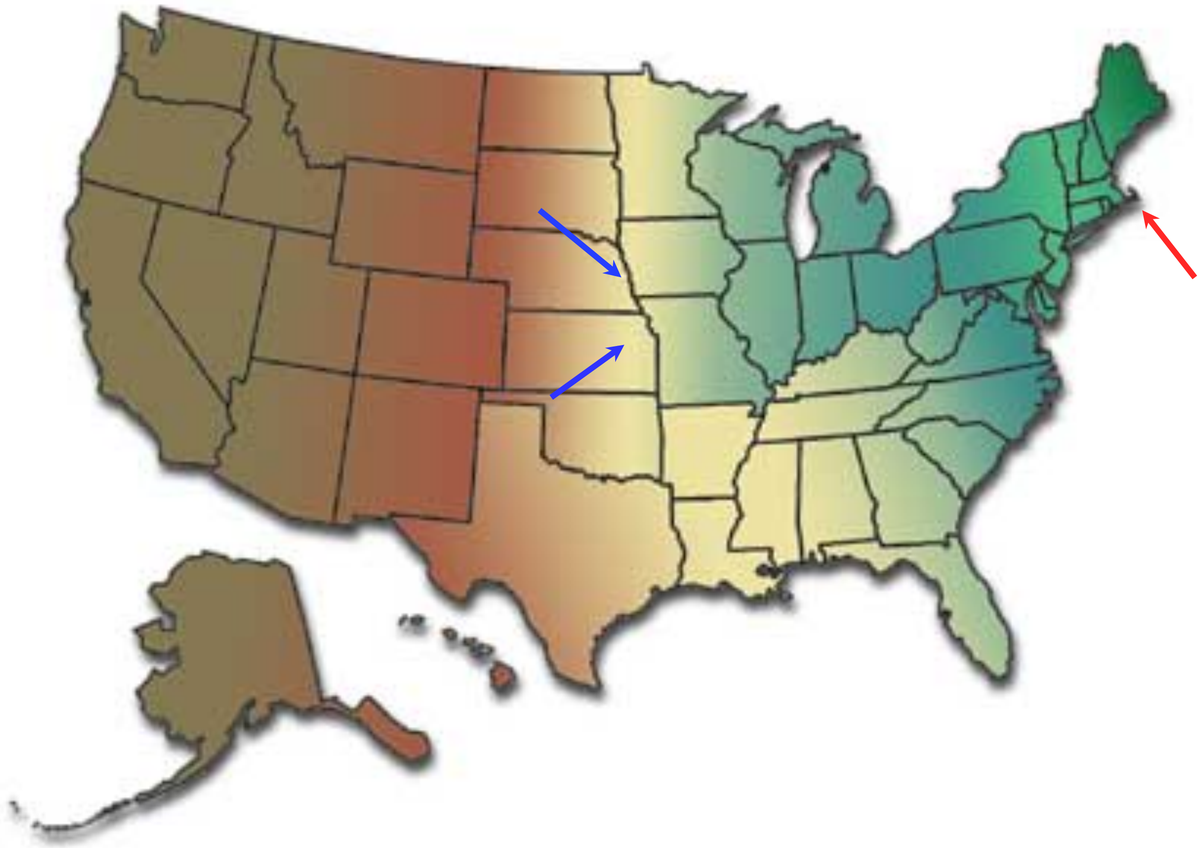
# course grading

- Practicals with RStudio: up to 3 points
- Multiple-choice test: up to 2 points

# Introduction to network theory

# social networks

160 letters from Wichita (Kansas) and  Omaha (Nebraska) to Sharon (Mass)



Milgram (1967)

# social networks

In the Nebraska study, the chains varied between 2 and 10 intermediate acquaintances, with the median at 5

What a small world!

El mundo es un pañuelo!

C’est petit le monde!

Die Welt ist klein!

Milgram (1967)

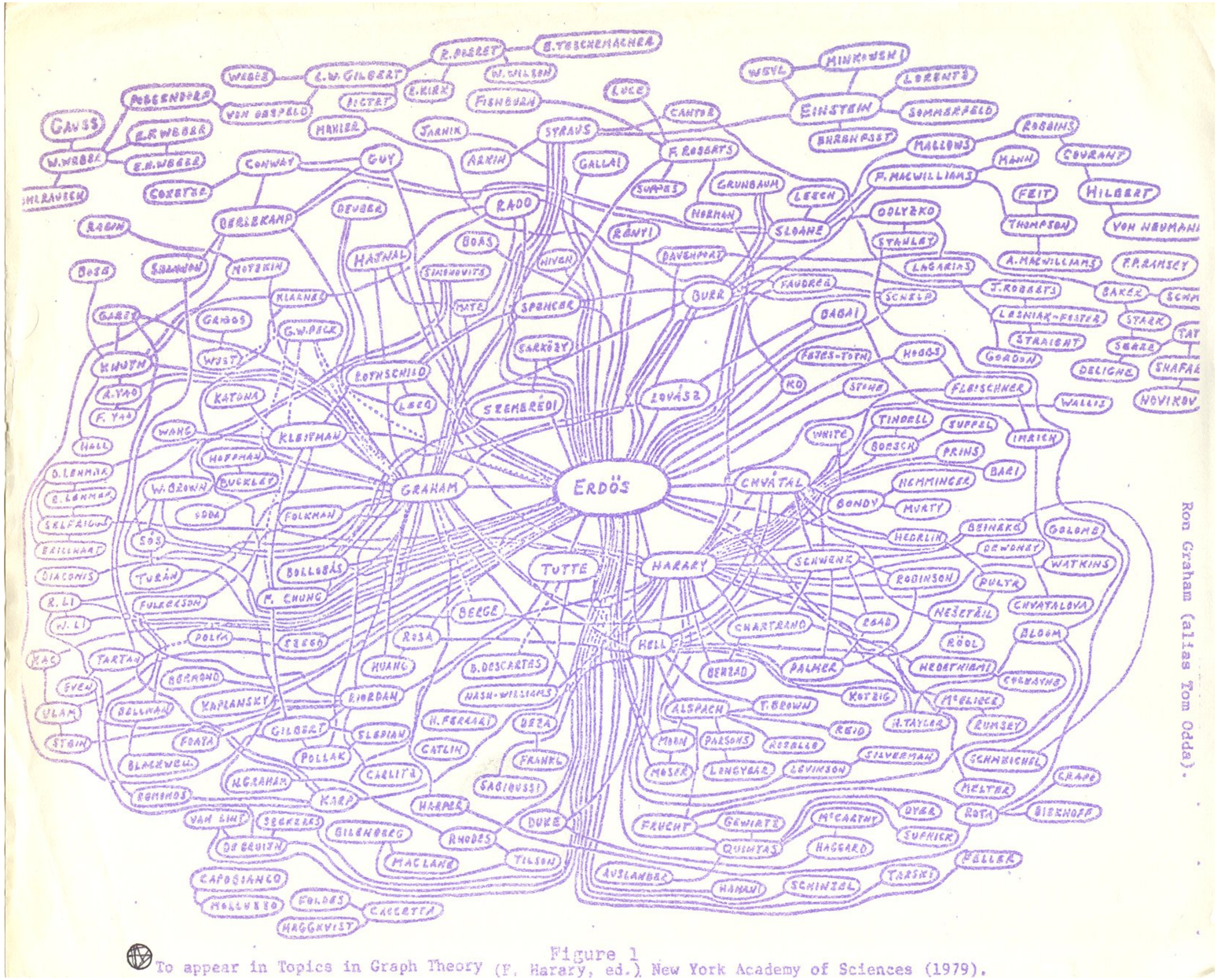
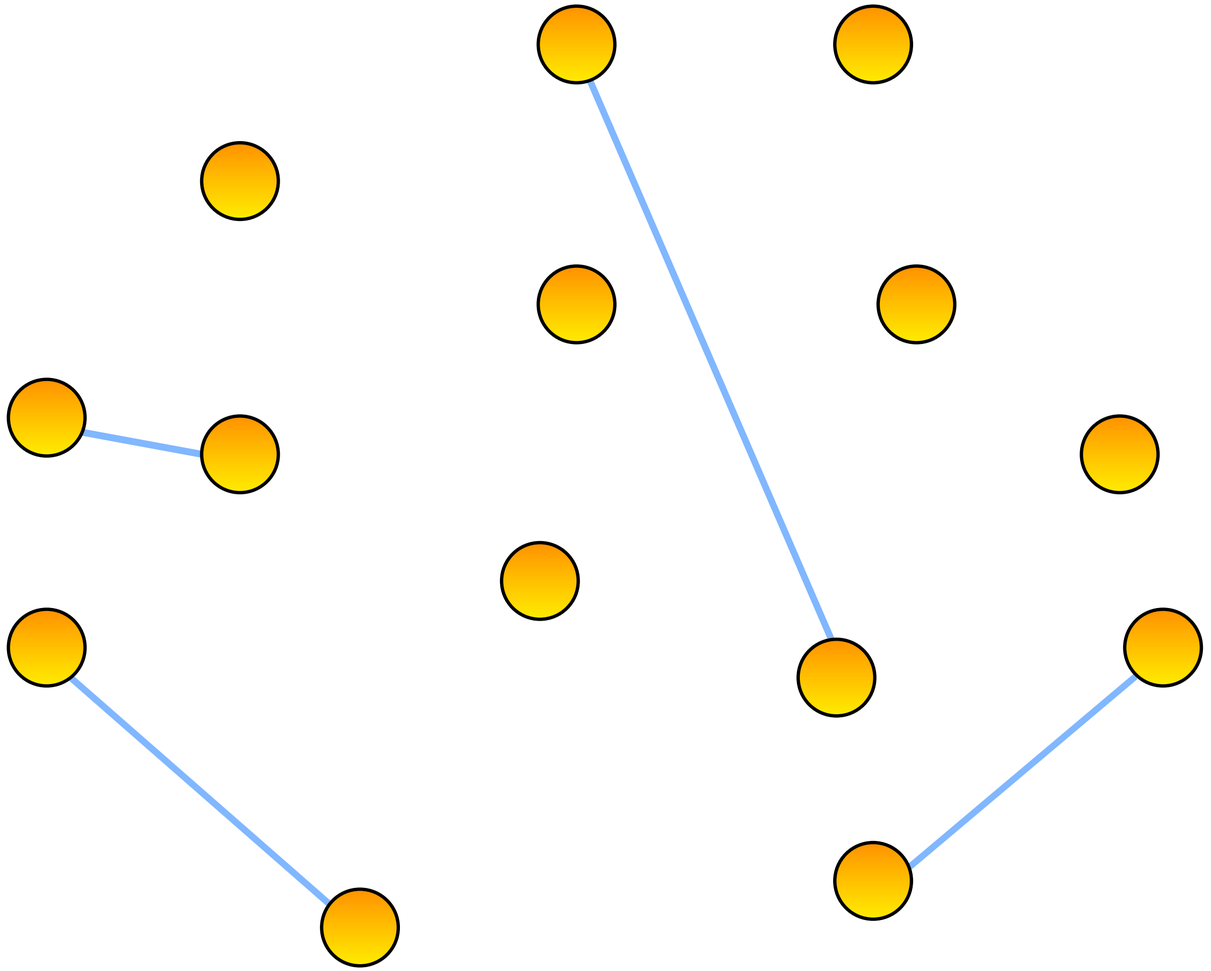


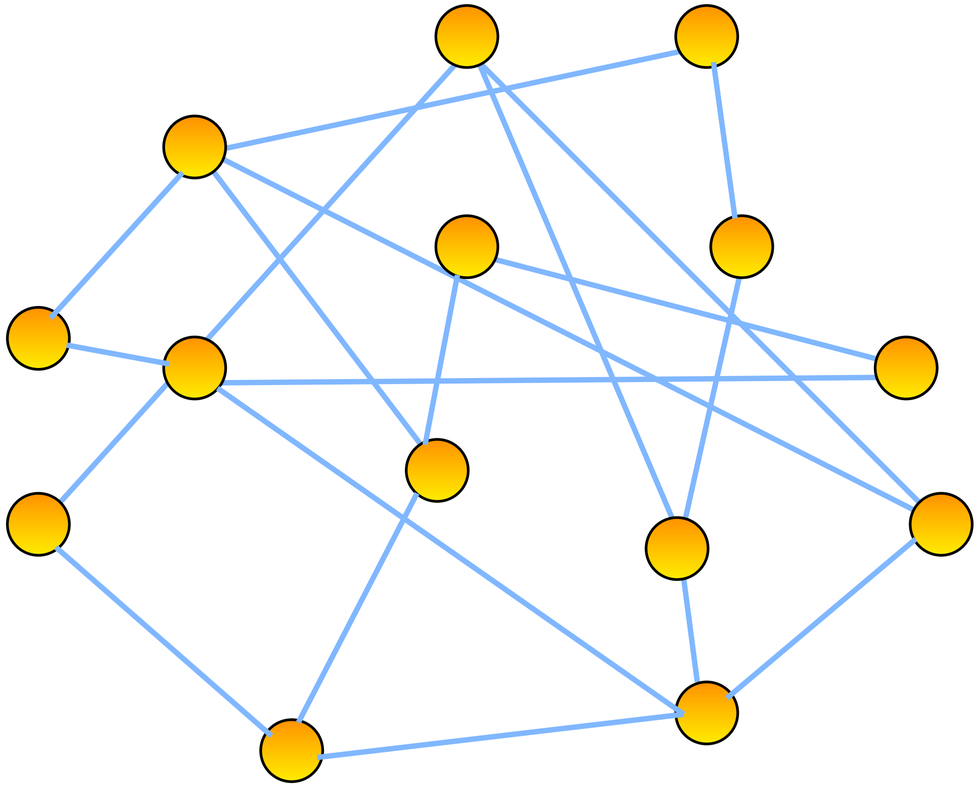

Figure 1

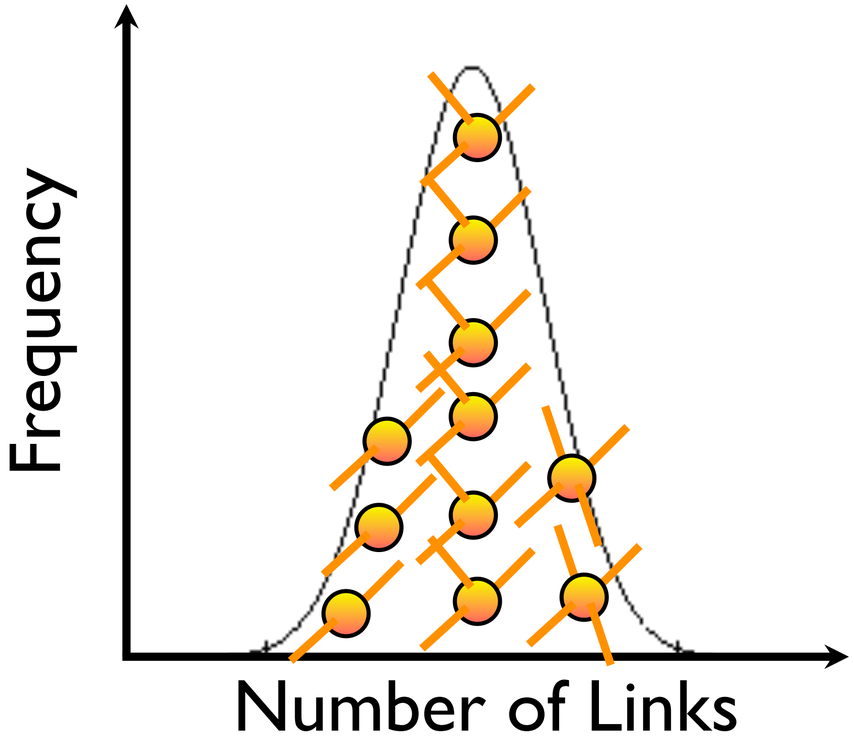
To appear in Topics in Graph Theory (F. Harary, ed.) New York Academy of Sciences (1979).

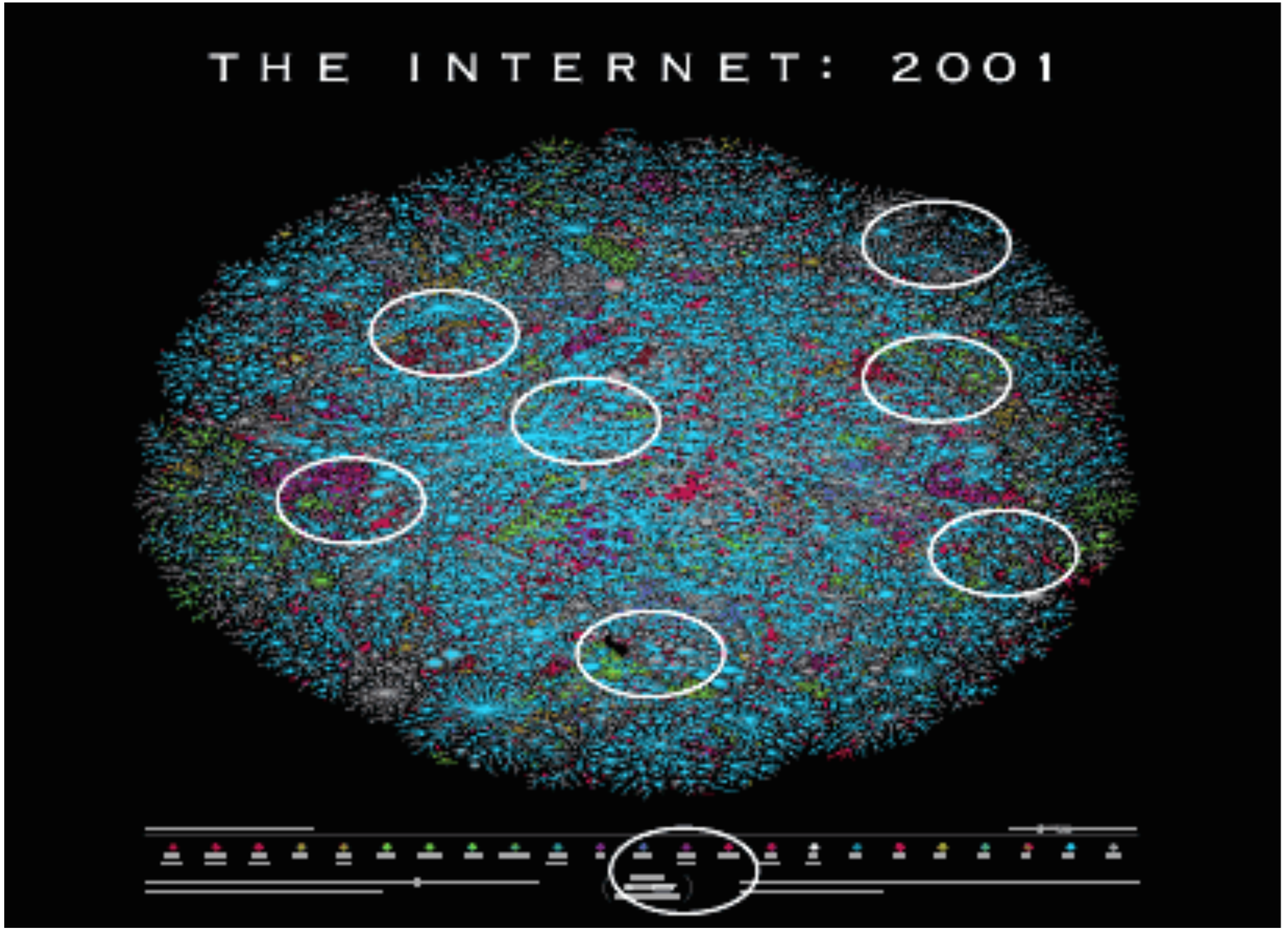
# Erdös-Rényi model

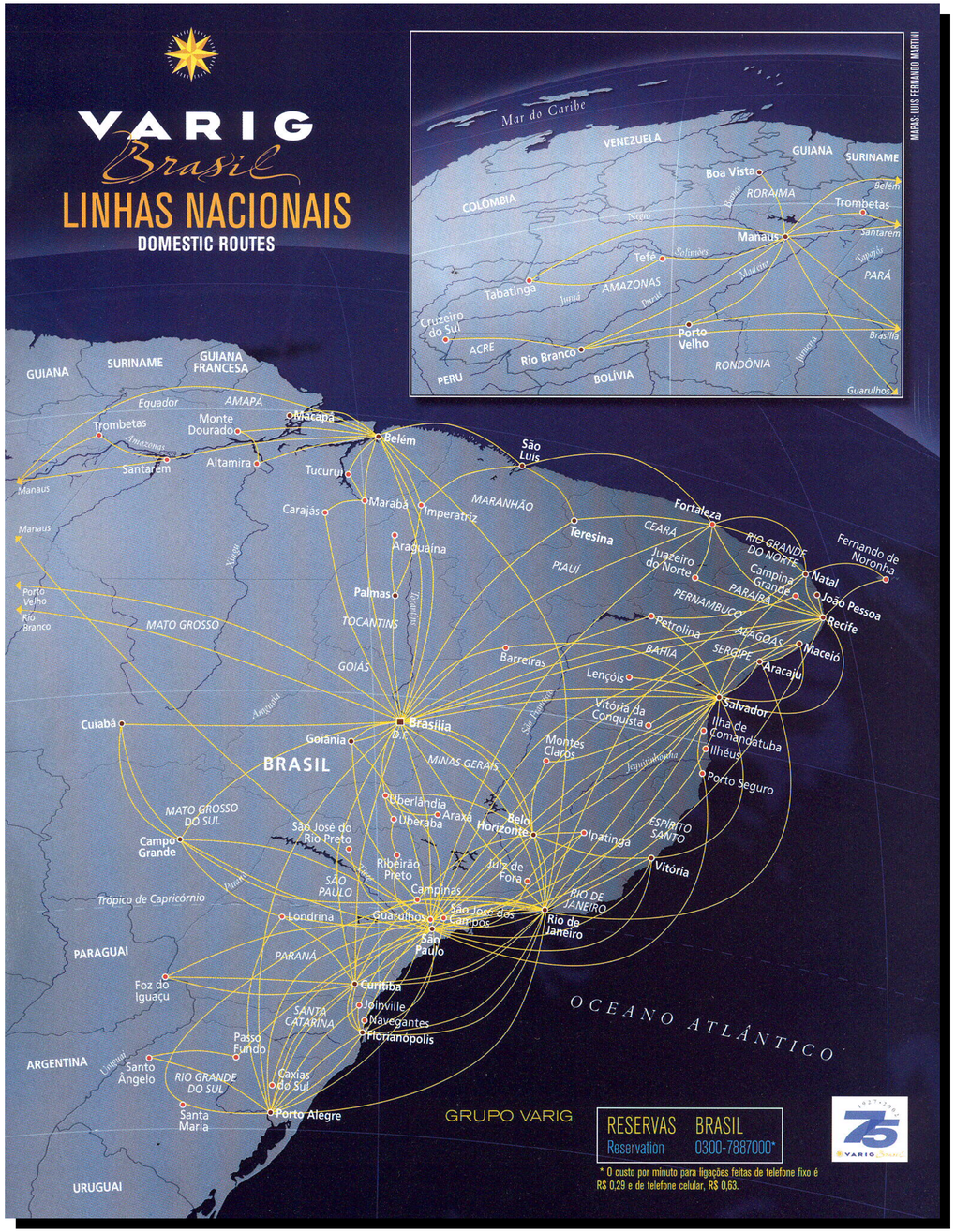


# Erdös-Rényi model






THE INTERNET: 2001


VARIG
Brasil
LINHAS NACIONAIS
DOMESTIC ROUTES
MAPAS: LUIS FERNANDO MARTINI
Mar do Caribe
VENEZUELA
GUIANA
SURINAME
COLÔMBIA
Boa Vista
RORAIMA
Belém
Trombetas
Manaus
Santarém
PARÁ
Tefé
Tabatinga
AMAZONAS
Cruzeiro do Sul
ACRE
Rio Branco
Porto Velho
RONDÔNIA
PERU
BOLÍVIA
Brasília
Guarulhos
GUIANA
SURINAME
GUIANA FRANCESA
Equador
AMAPÁ
Macapá
Monte Dourado
Altamira
Tucuruí
São Luís
Carajás
Marabá
Imperatriz
MARANHÃO
Fortaleza
CEARÁ
Teresina
PIAUÍ
Juazeiro do Norte
RIO GRANDE DO NORTE
Fernando de Noronha
Natal
Campina Grande
PARAÍBA
João Pessoa
PERNAMBUCO
Recife
Petrolina
ALAGOAS
Maceió
BAHIA
SERGIPE
Aracaju
Barreiras
Lençóis
Araguaína
Palmas
TOCANTINS
MATO GROSSO
GOIÁS
Cuiabá
Goiânia
Brasília
D.F.
Salvador
Vitória da Conquista
Ilha de Comandatuba
Ilhéus
Porto Seguro
Montes Claros
MINAS GERAIS
BRASIL
Uberlândia
Araxá
Uberaba
Belo Horizonte
Ipatinga
ESPÍRITO SANTO
Vitória
MATO GROSSO DO SUL
São José do Rio Preto
Campo Grande
Ribeirão Preto
Juiz de Fora
SÃO PAULO
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Tropico de Capricórnio
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Joinville
SANTA CATARINA
Navegantes
Florianópolis
Passo Fundo
ARGENTINA
Santo Ângelo
RIO GRANDE DO SUL
Caxias do Sul
Santa Maria
Porto Alegre
URUGUAI
OCEANO ATLÂNTICO
GRUPO VARIG
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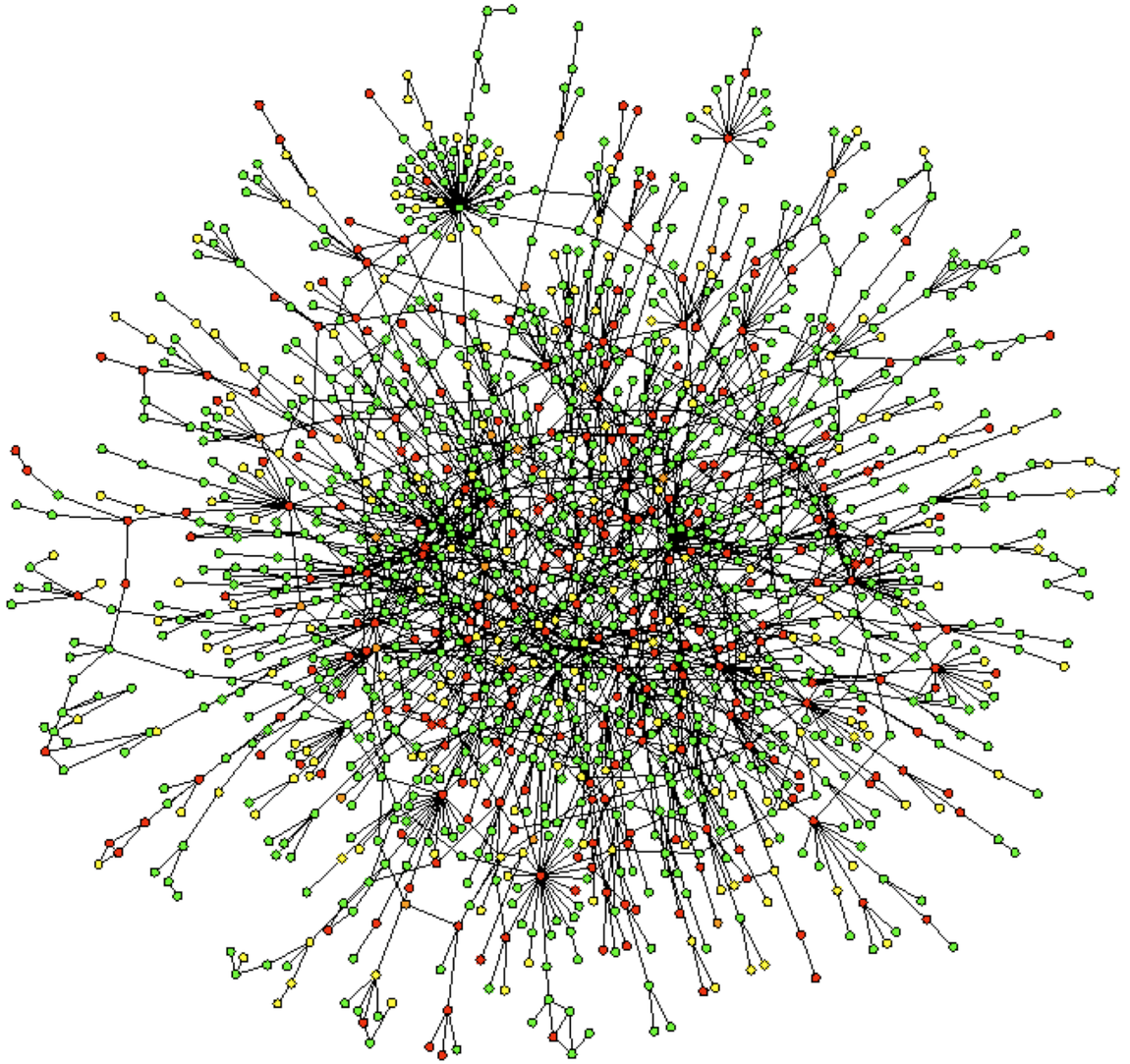
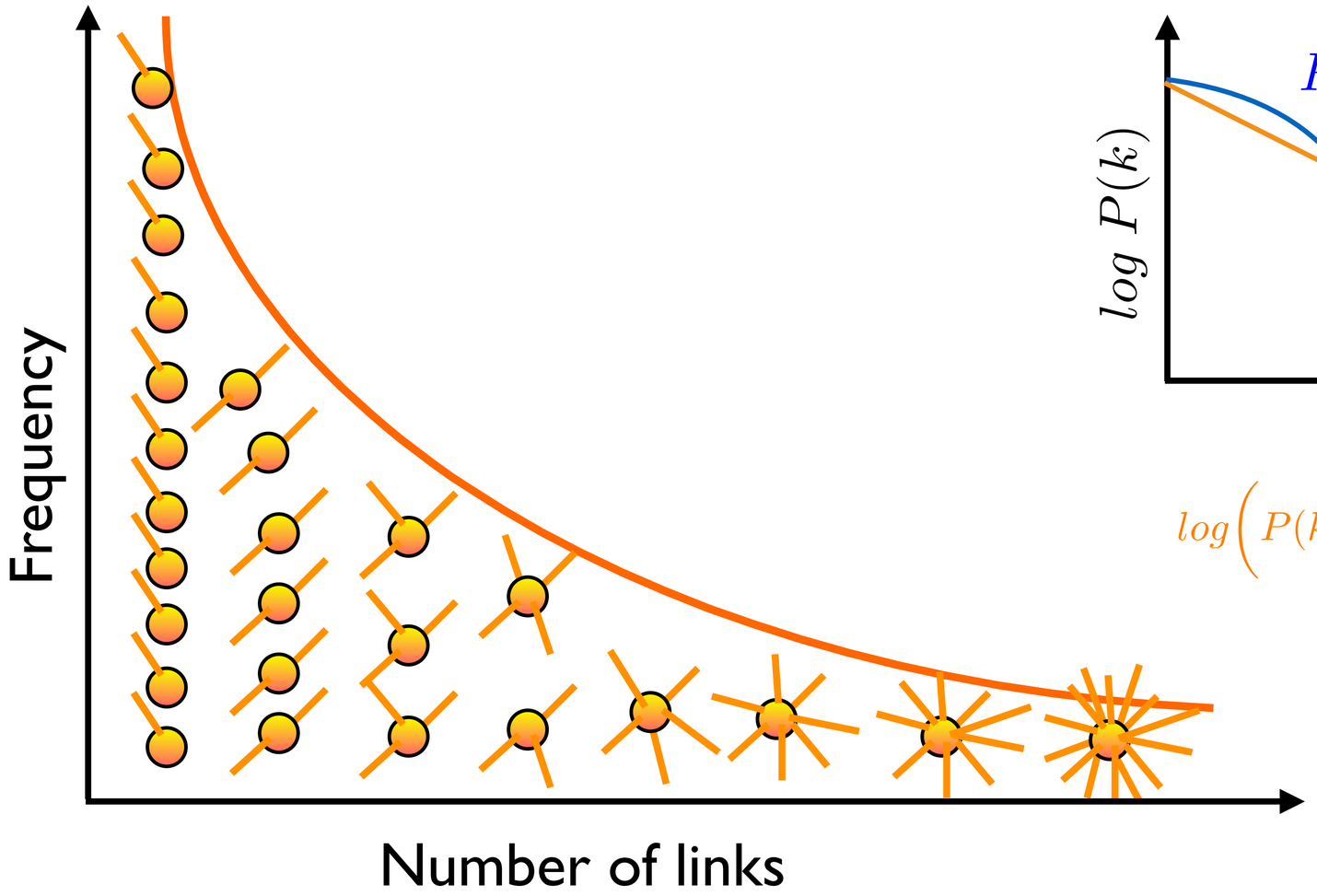
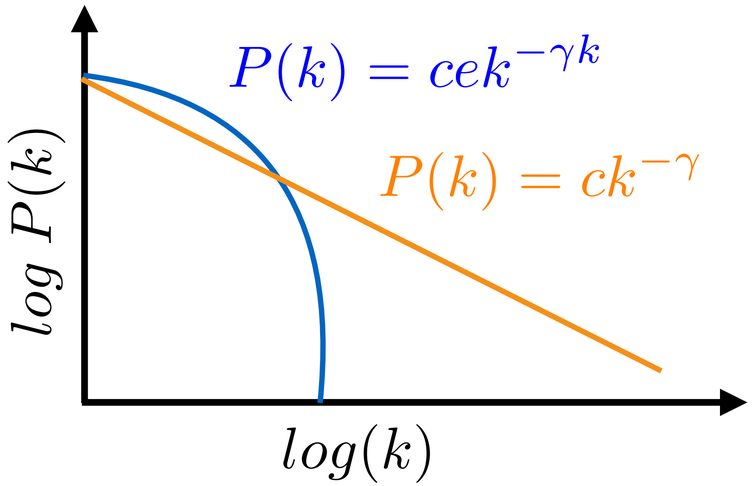
* O custo por minuto para ligações feitas de telefone fixo é R$ 0,29 e de telefone celular, R$ 0,63.
75

# protein networks



# complex networks are heterogeneous



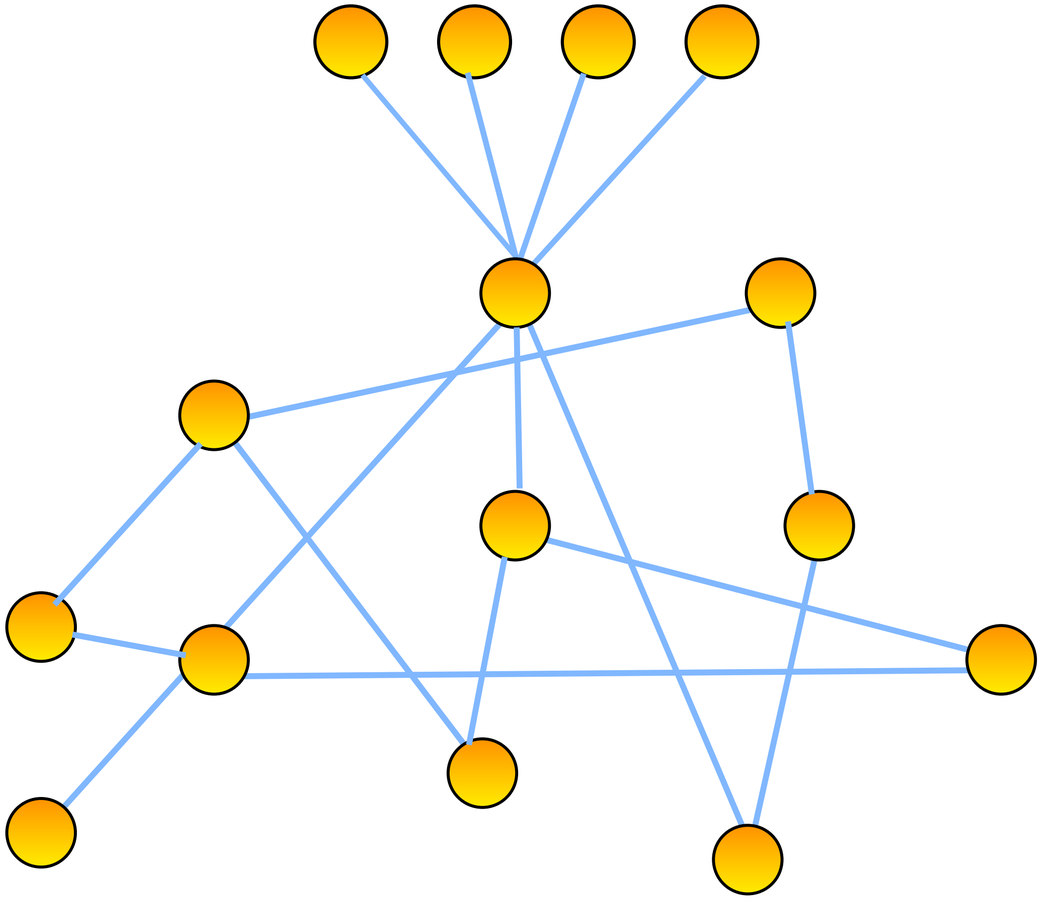

$$log\Big(P(k)\Big) = log(c) - \gamma\ log(k)$$

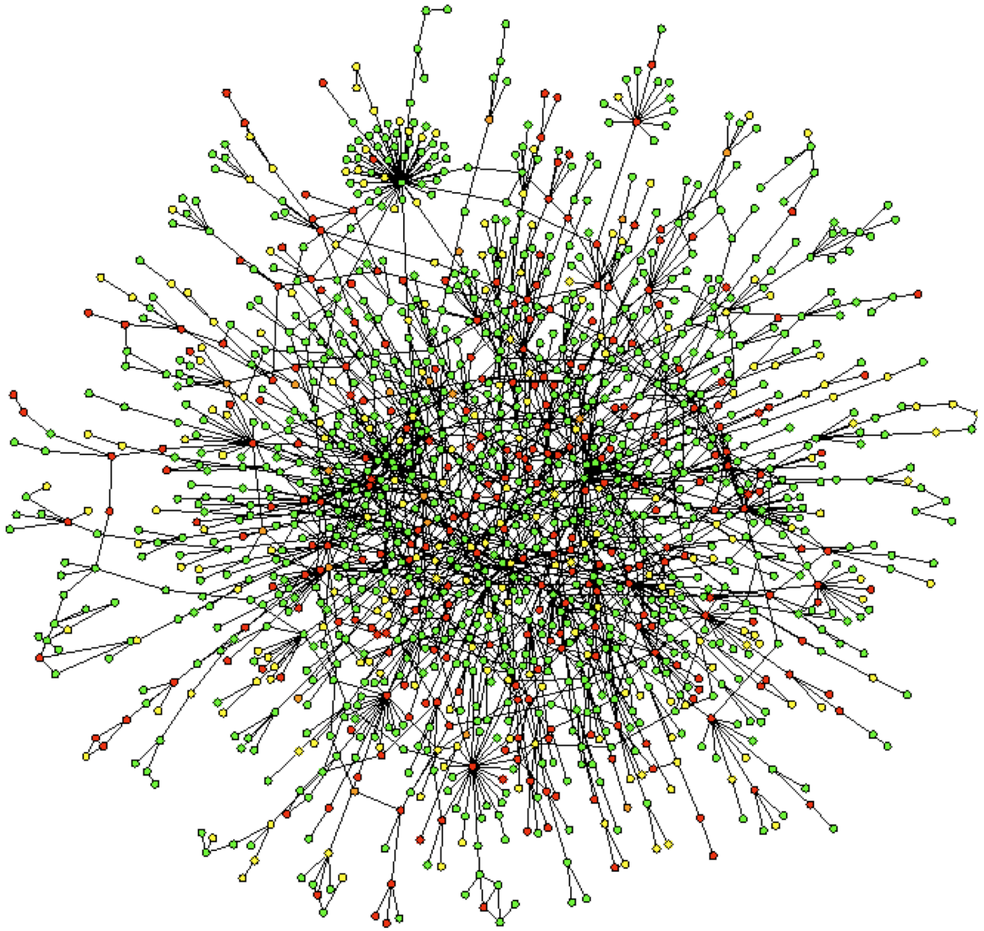
Most real networks have the same internal structure

Why?

What are the implications?

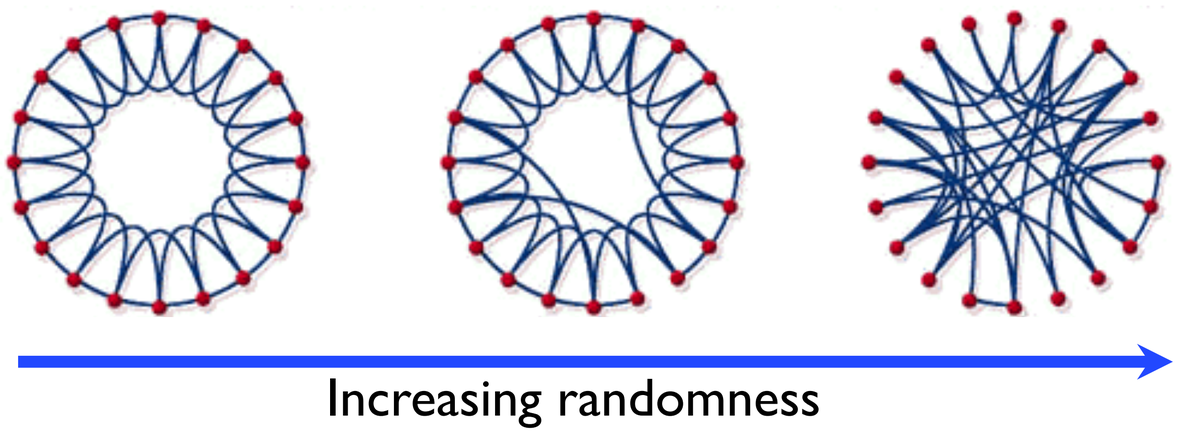
# preferential attachment

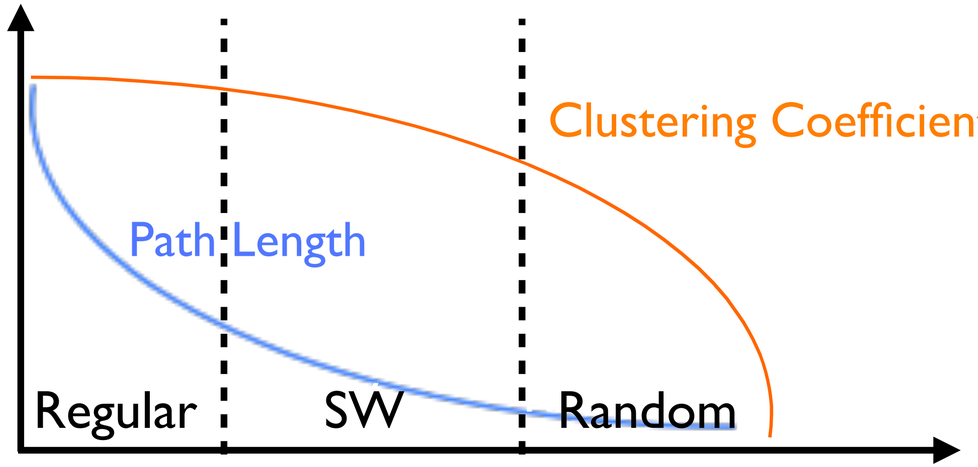




Rich get richer!

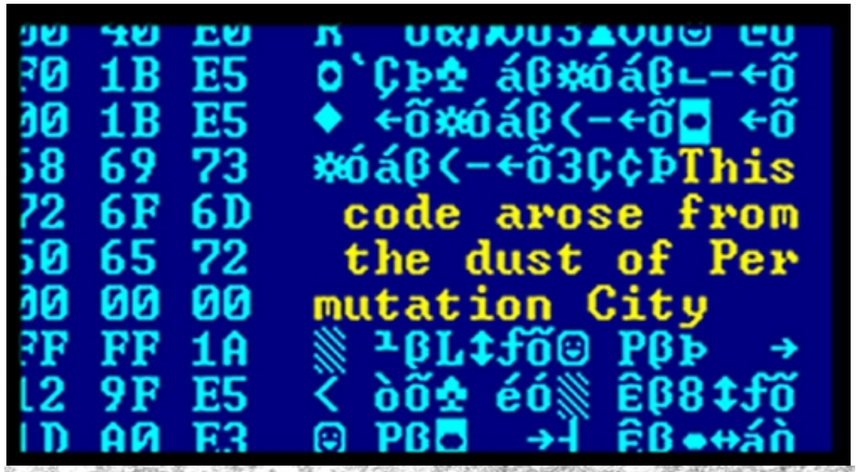
# back to the small world

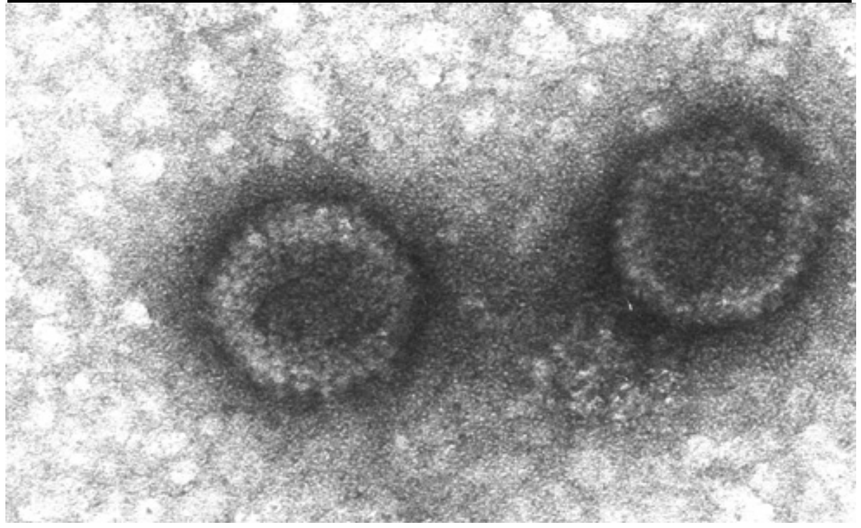



Watts and Strogatz (1998)

# eradication in viruses



infection rate

spreading rate

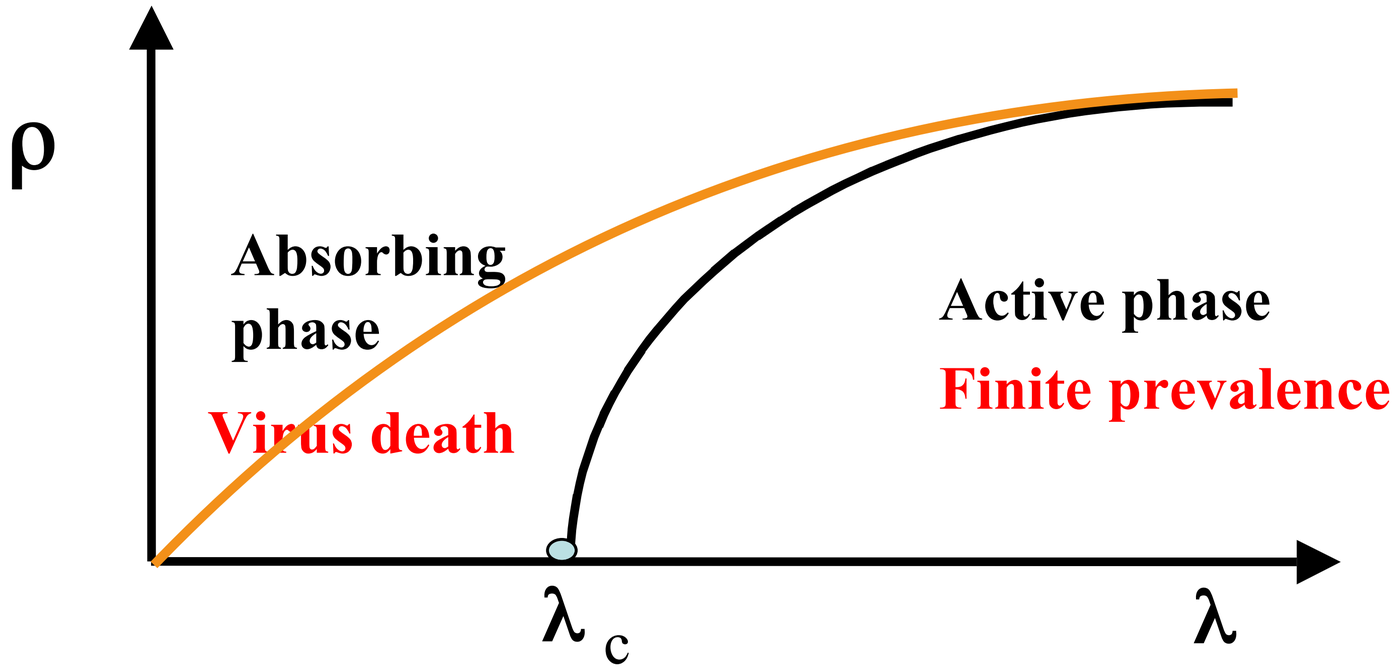
$$\lambda = \frac{\mu}{\delta}$$

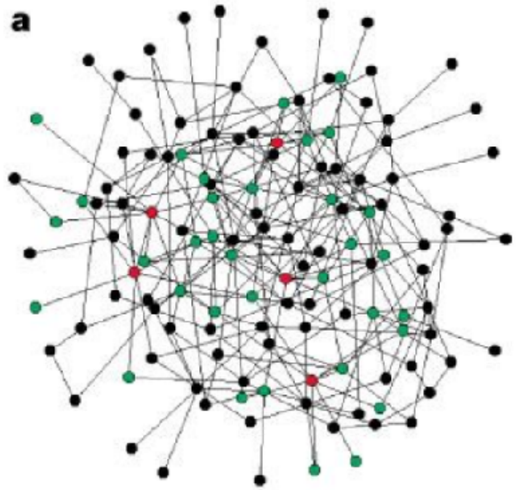
recovery rate

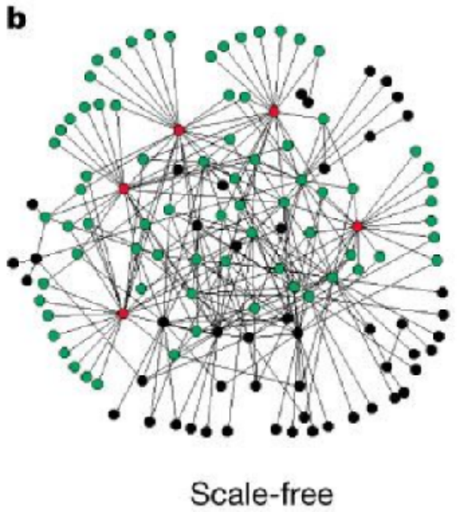
prevalence

$$\rho = 1 - \frac{\delta}{\mu}$$

# eradication in viruses

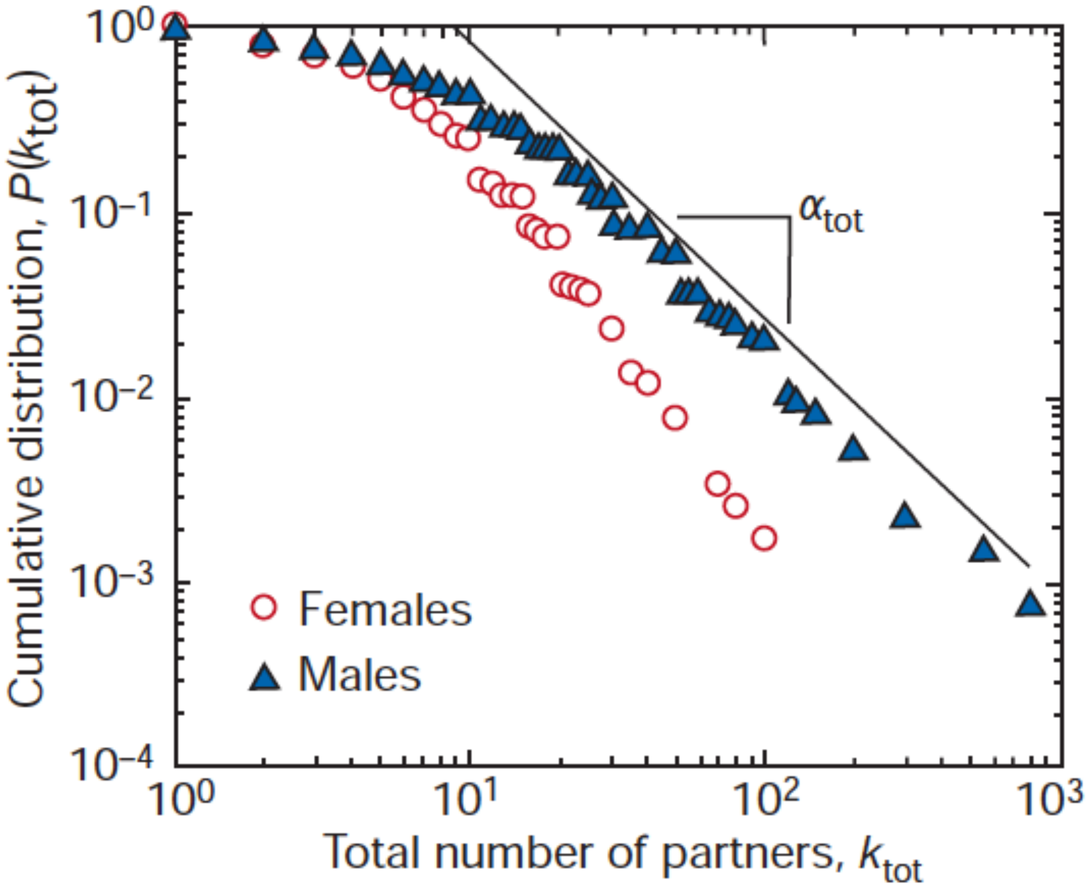


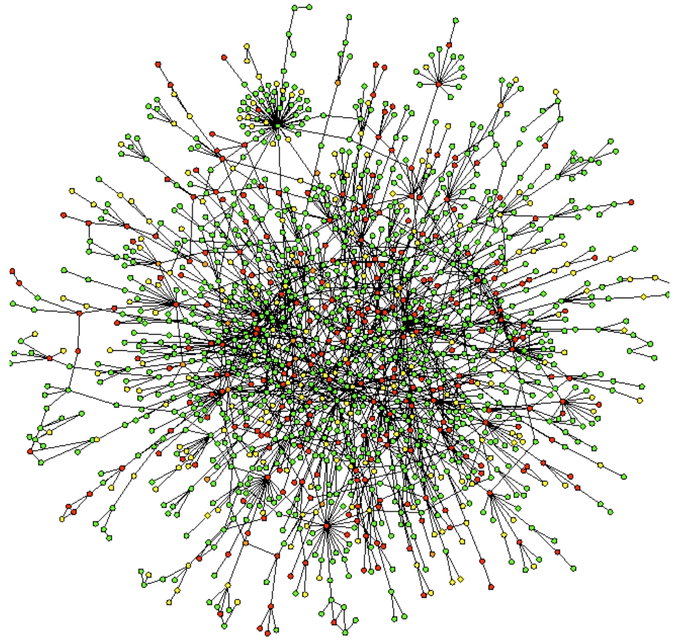




Pastor Satorras and Vespignani (2001)

# sexually transmitted diseases

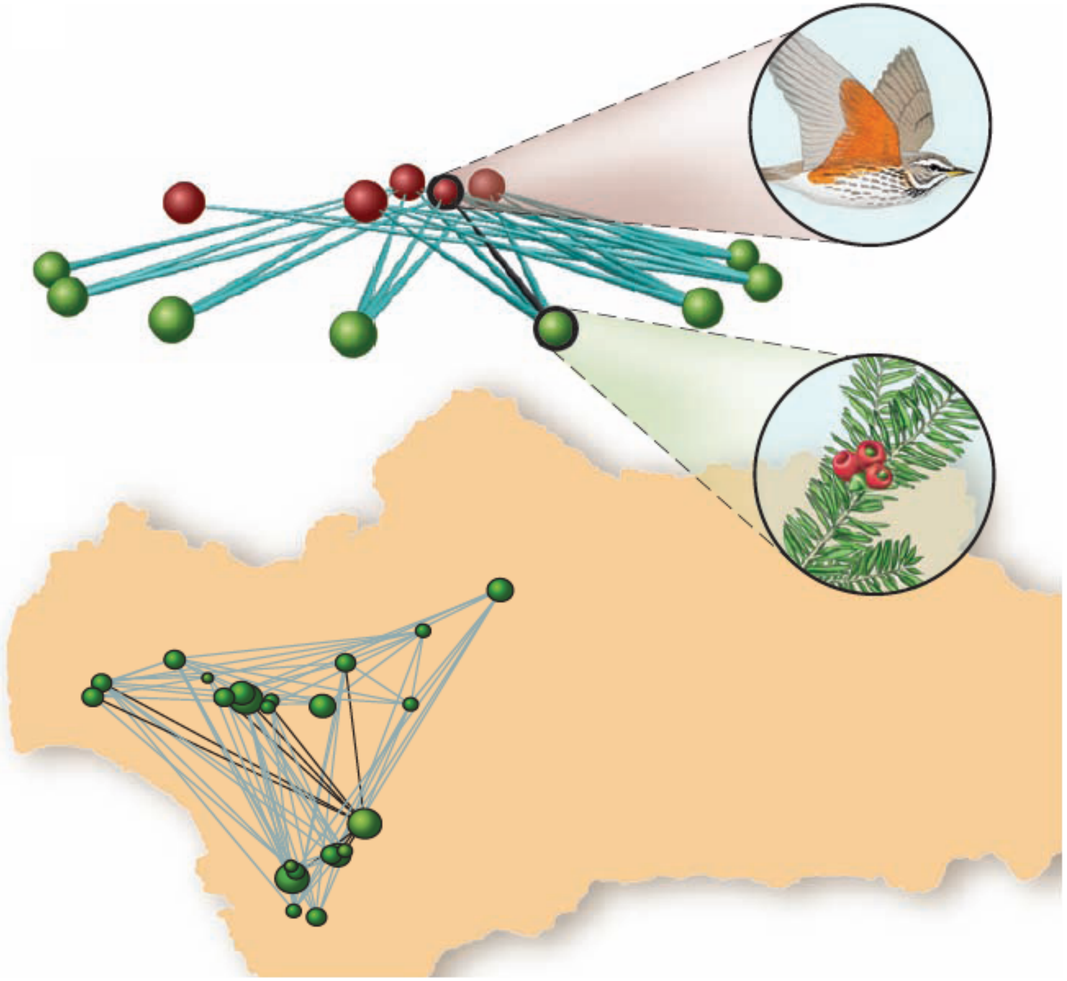


Absence of eradication thresholds in scale-free networks

Lijeros *et al.* (2001)

# wrapping up: why networks?



- networks allow introducing heterogeneity into our previous homogeneous theories.
- networks put the focus on the patterns of interactions among elements.
- networks allow searching for commonalities among disparate systems.