BIO 365 ecological networks

coordinators: Jordi Bascompte and Alessandro Vindigni

co-teachers: Matt Barbour, Rodrigo Cámara-Leret, Marília Gaiarsa, Klementyna Gawecka, Matt Hutchinson, Eva Knop, Fernando Pedraza

Introduction to course

outline of course

From	To		Thursday March 17	Friday March 18	Tuesday March 22	Wednesday March 23	Thursday March 24	Friday March 25	Tuesday March 29	Wednesday March 30	Thursday March 31	Friday April 1	Tuesday April 5	Wednesday April 6	Thursday April 7
10:15	12:00	LECTURE	Outline and Intro	Food webs		Mutualistic networks	Null models	Statistical approaches		Spatial networks	Animal behaviour	Evolution in networks		Socio-ecological networks	Open time
	Speaker	LECTURE	Bascompte	Gaiarsa		Bascompte	Bascompte	Barbour		Gawecka	Hutchinson	Pedraza		Cámara-Leret	office hours (with appointment)
12:00	13:00		Lunch		Lunch	Lunch	Lunch	Lunch	Lunch	Lunch	Lunch	Lunch		Lunch	Lunch
	Lead	EXERCISE	Vindigni	Gaiarsa	Knop	Gawecka	Pedraza	Barbour	Vindigni	Gawecka	Hutchinson	Pedraza		Cámara-Leret	Vindigni
13:00	17:00	EXERCISE	Toolkit for network analysis	Measuring modularity	Sampling an ecological network	Measuring nestedness	Null models	Statistical models	Assessing topological robustness	Comparing networks in space	Simulating foraging	Models of evolution in networks	Open time	Socio-ecological networks	Exam

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

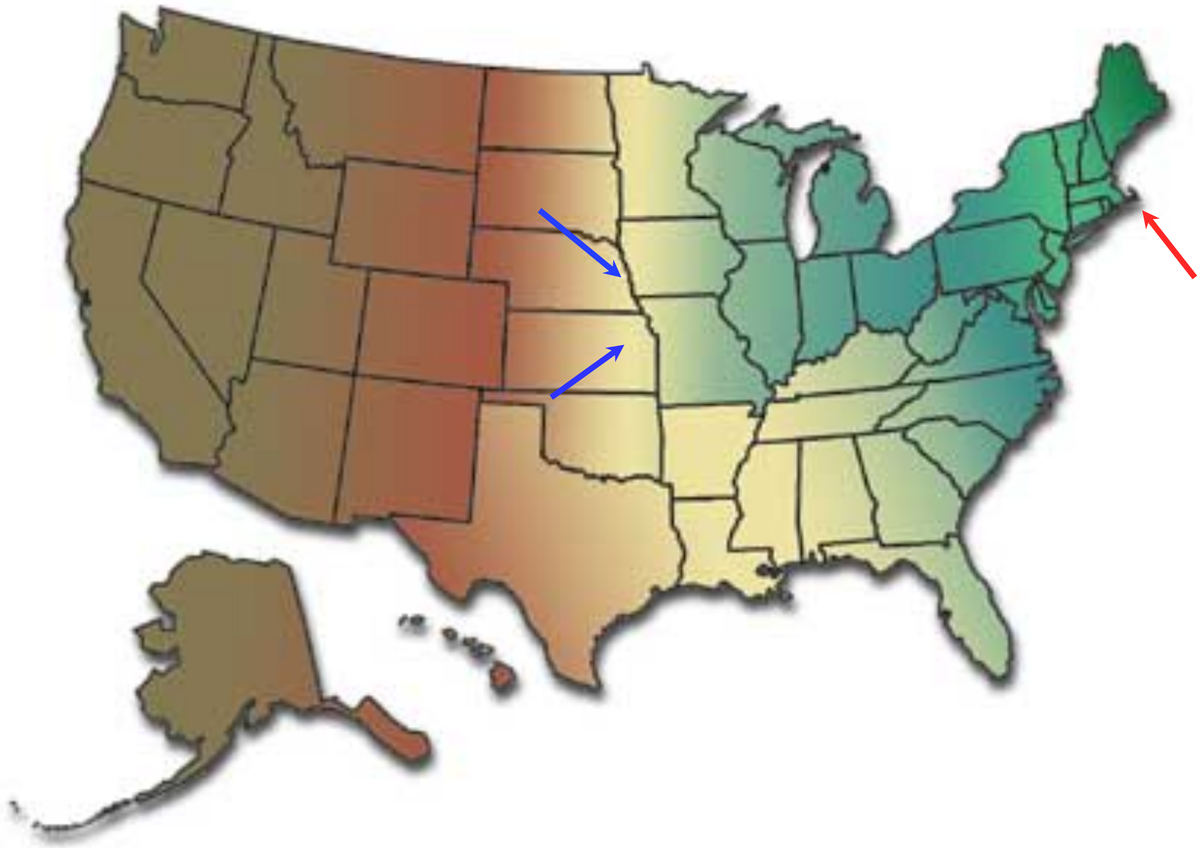
course grading

- Practicals with web-based RStudio environment, up to three points.
- Written exam: multiple-choice test, up to two 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)

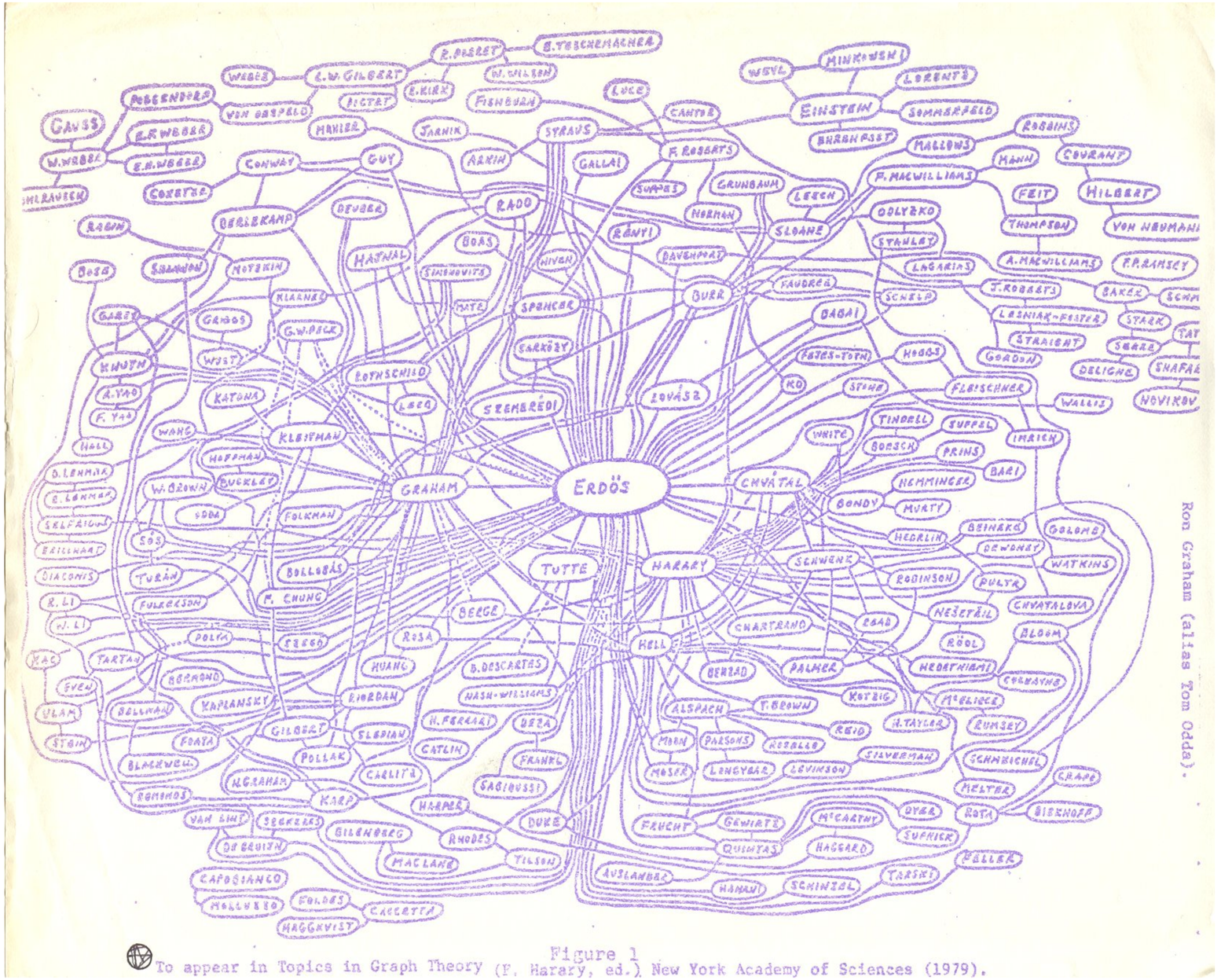
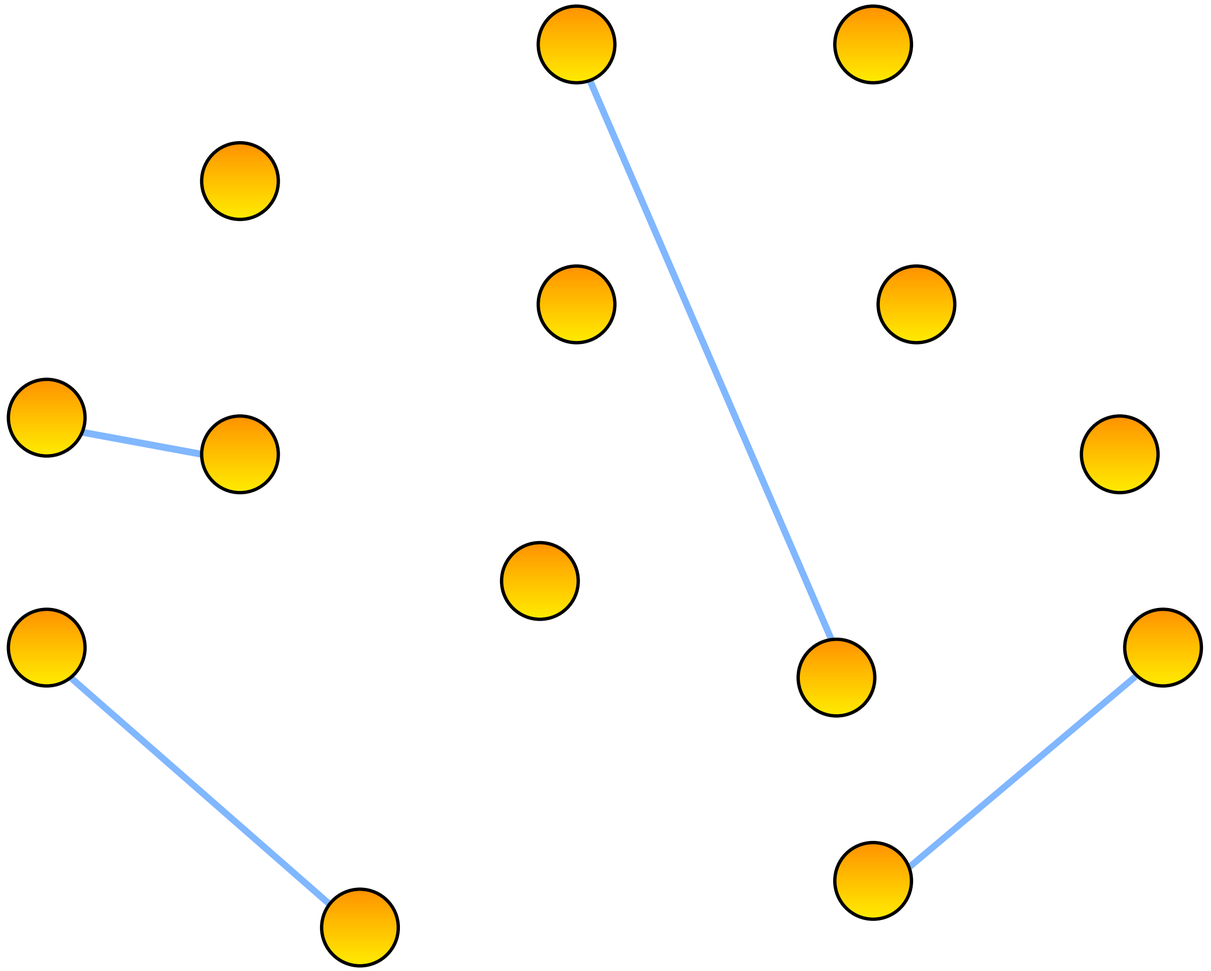


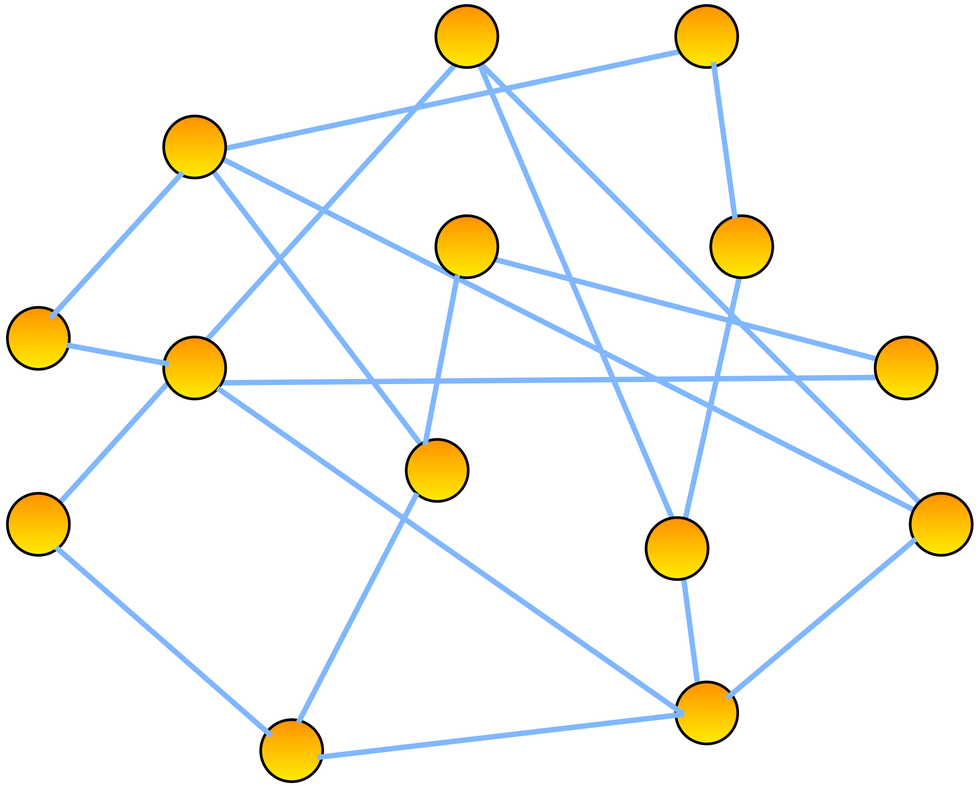
Figure 1

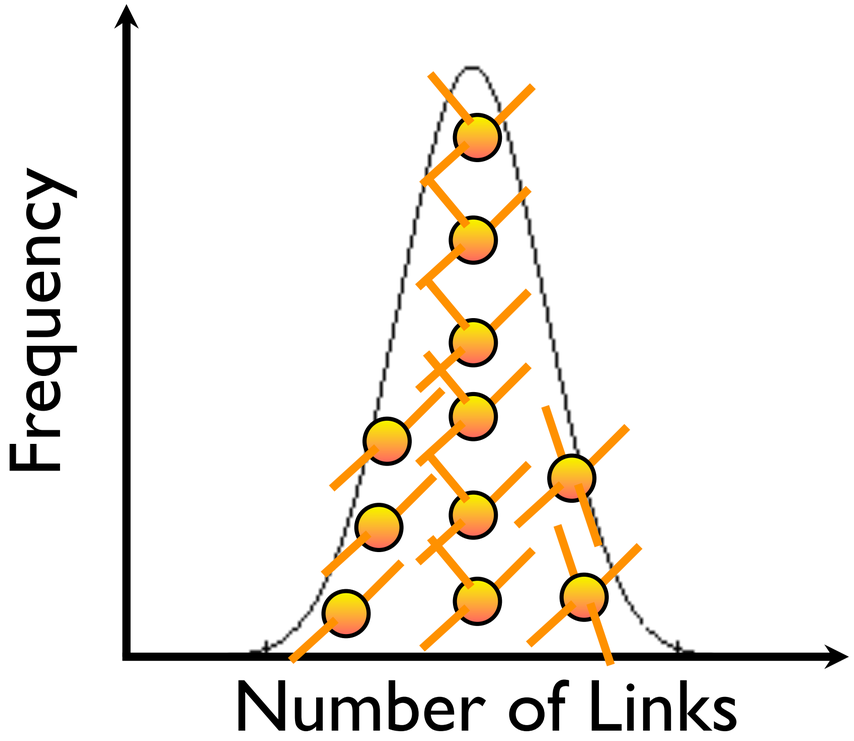
To appear in Topics in Graph Theory (F. Harary, ed.) New York Academy of Sciences (1979).

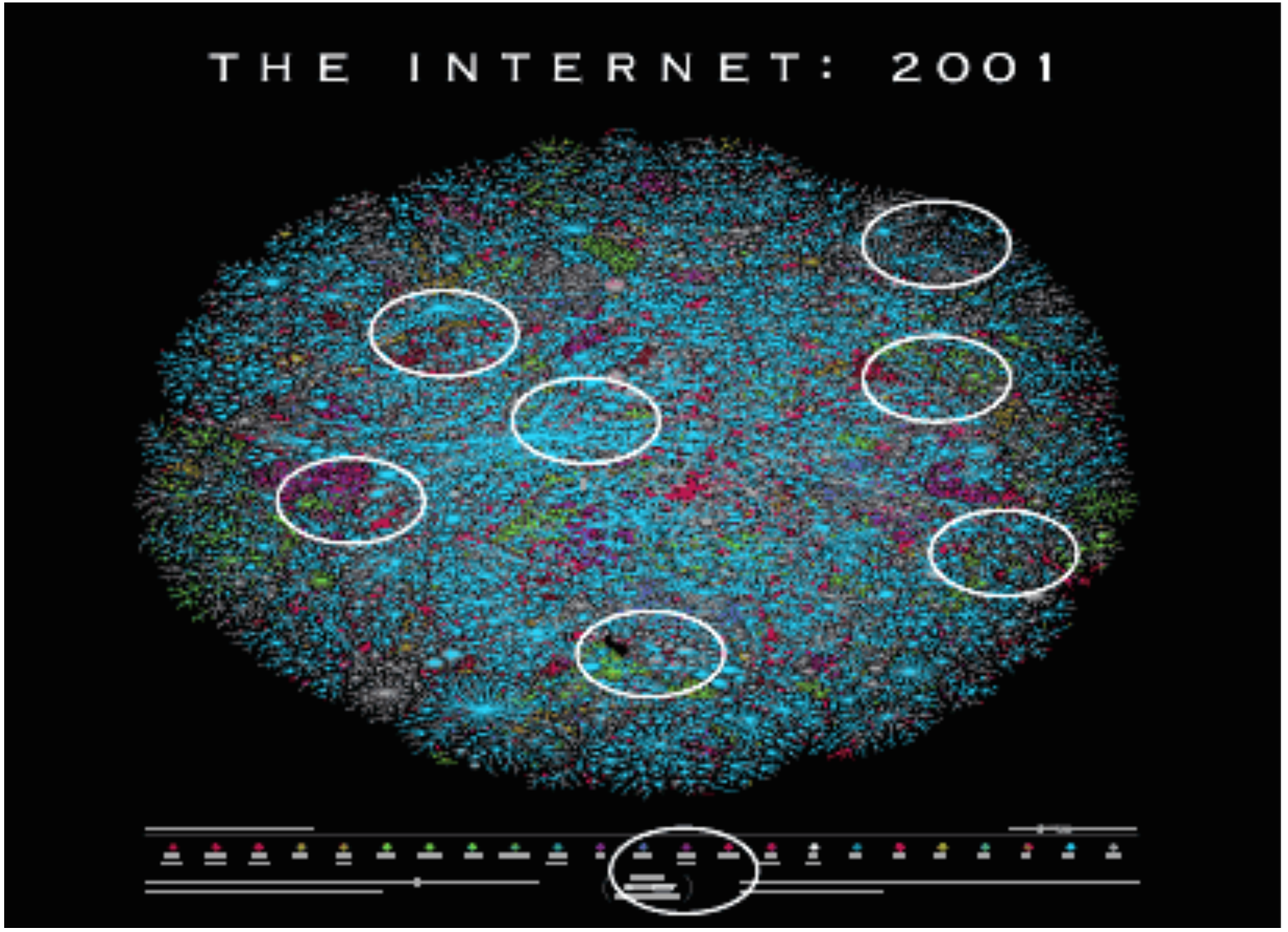
Erdös-Rényi model

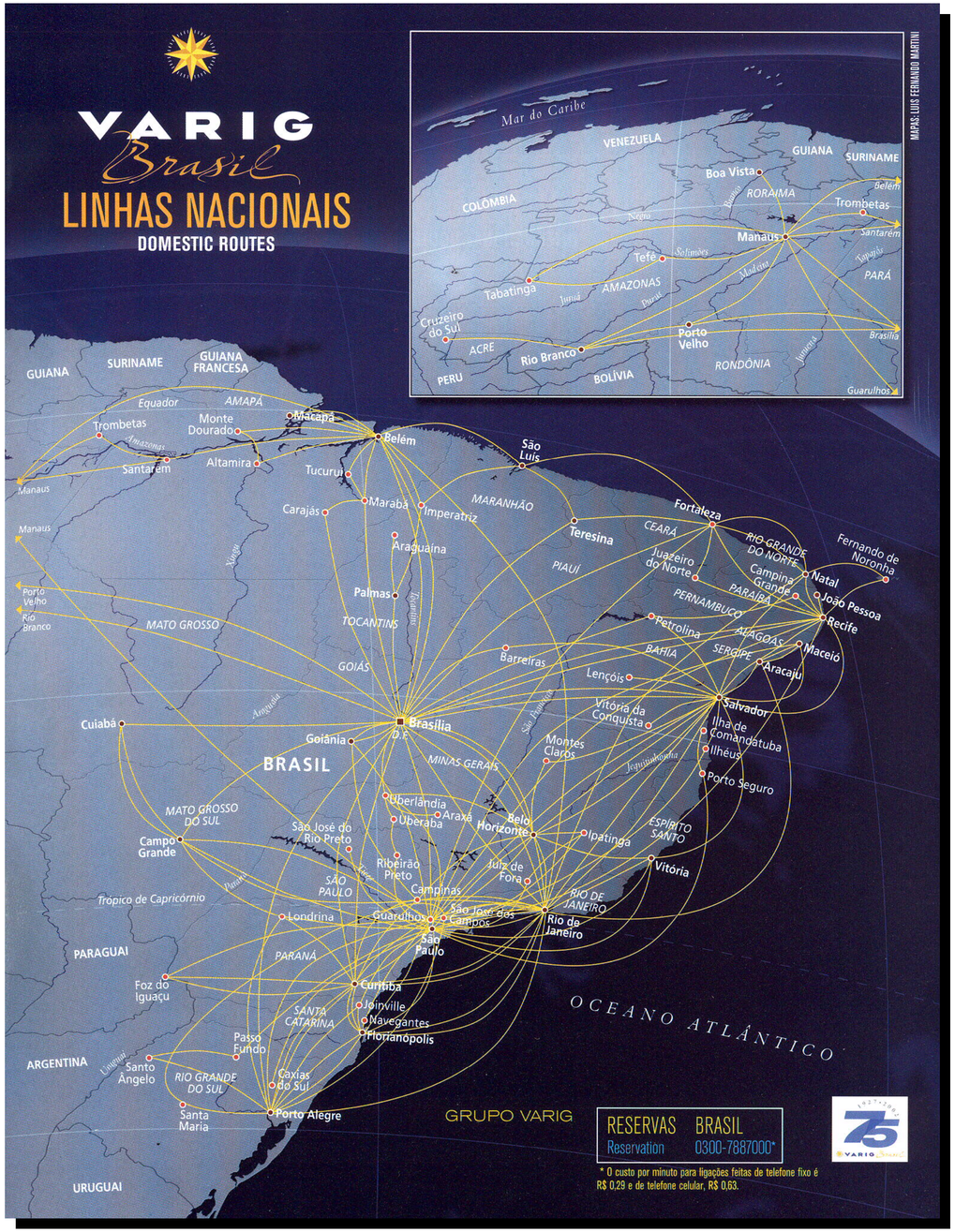


Erdös-Rényi model






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
Campinas
RIO DE JANEIRO
Tropico de Capricórnio
Londrina
Guarulhos
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Rio de Janeiro
São Paulo
PARAGUAI
PARANÁ
Foz do Iguaçu
Curitiba
Joinville
SANTA CATARINA
Navegantes
Florianópolis
Passo Fundo
ARGENTINA
Santo Ângelo
RIO GRANDE DO SUL
Caxias do Sul
Santa Maria
Porto Alegre
URUGUAI
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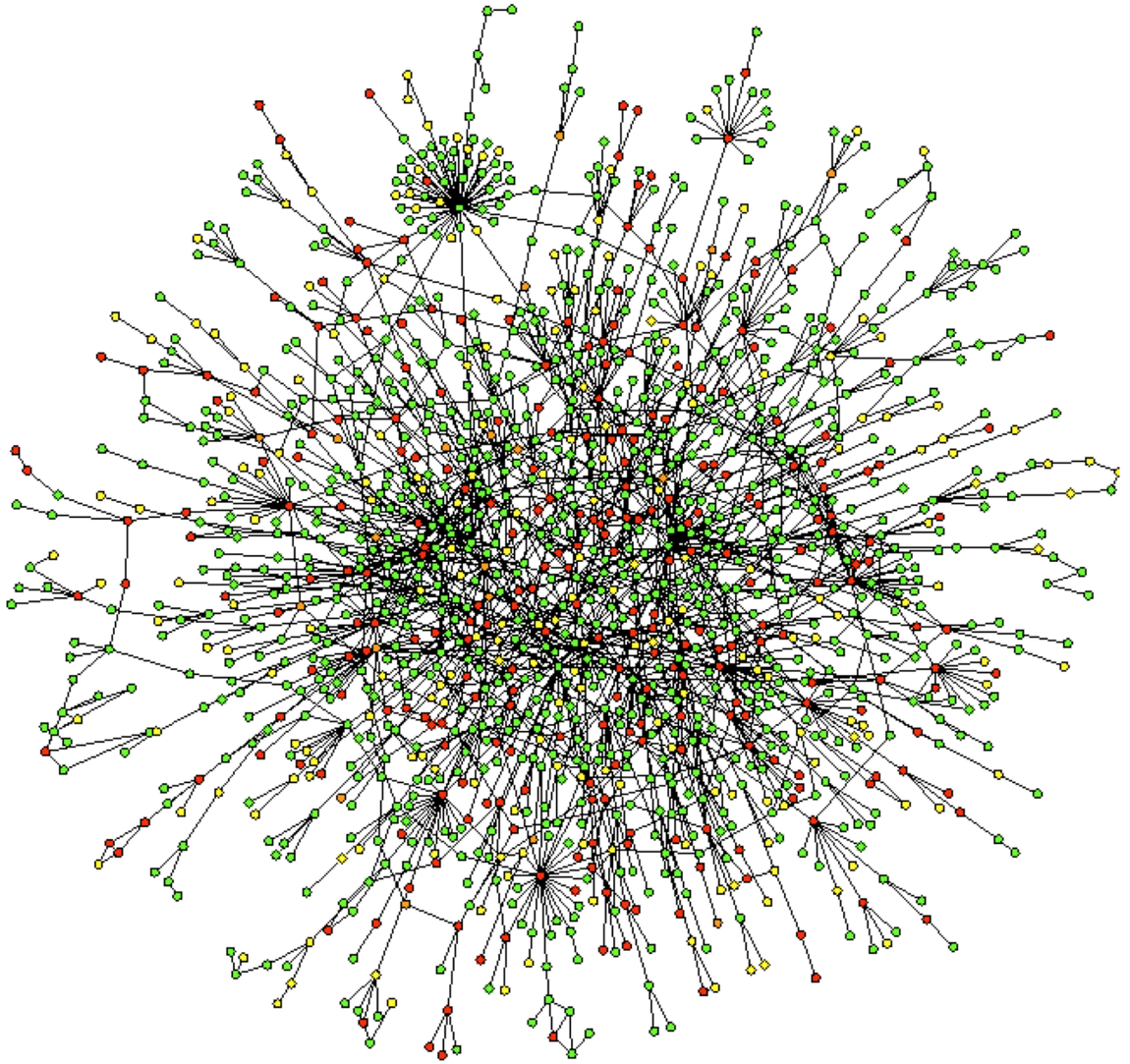
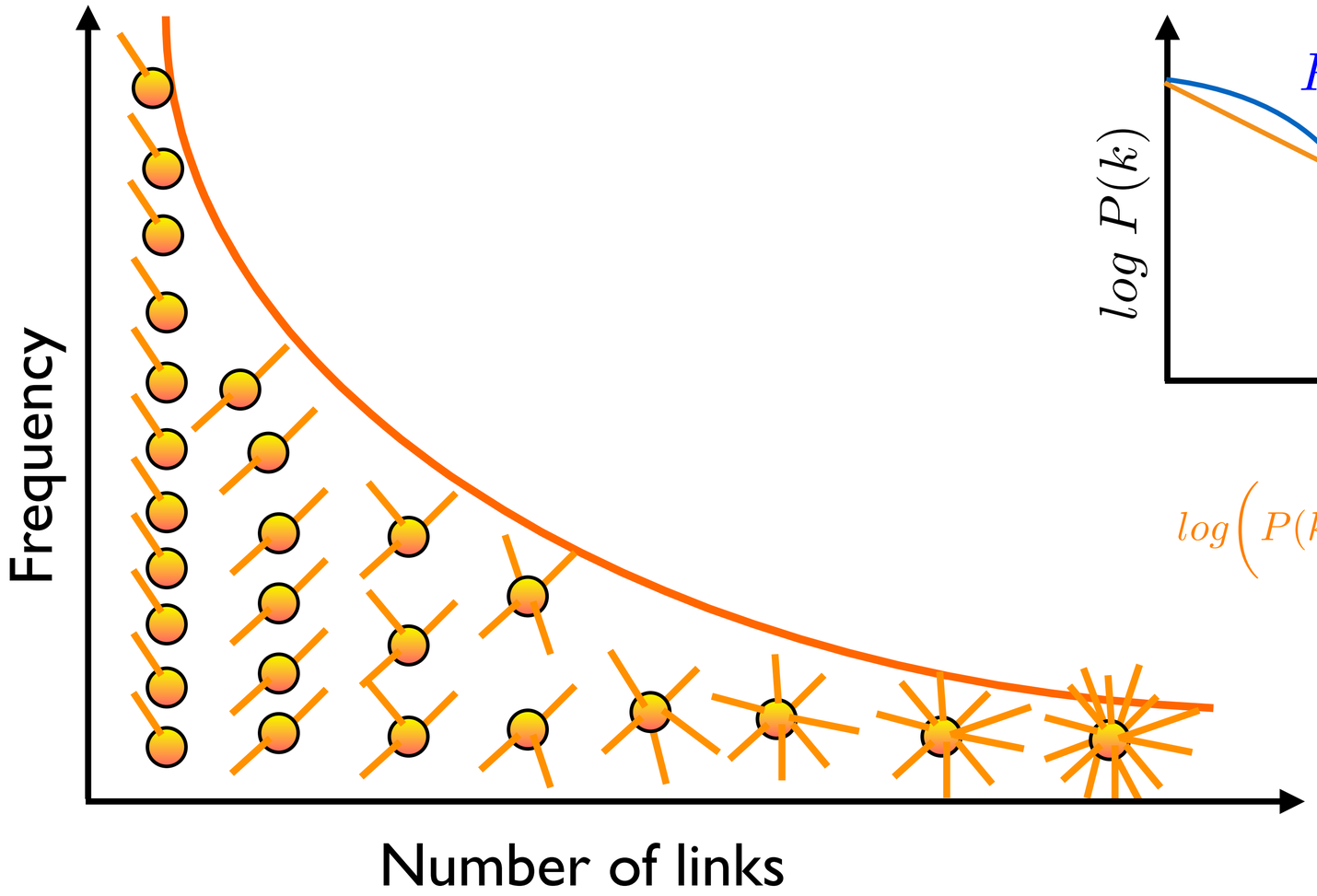
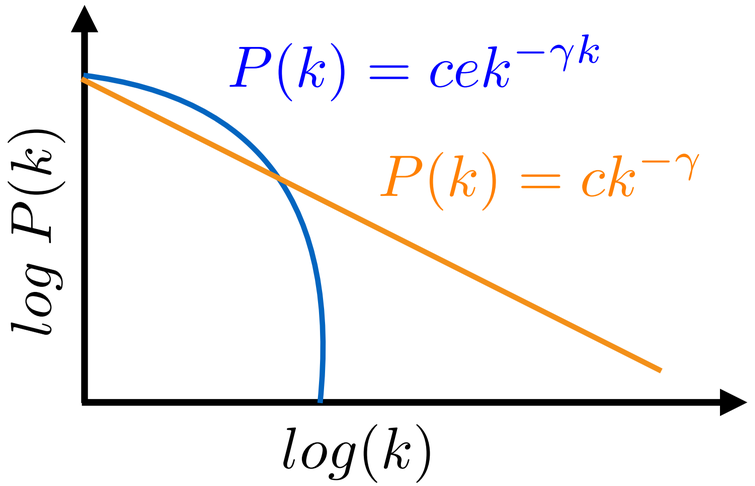
75

protein networks



complex networks are heterogeneous





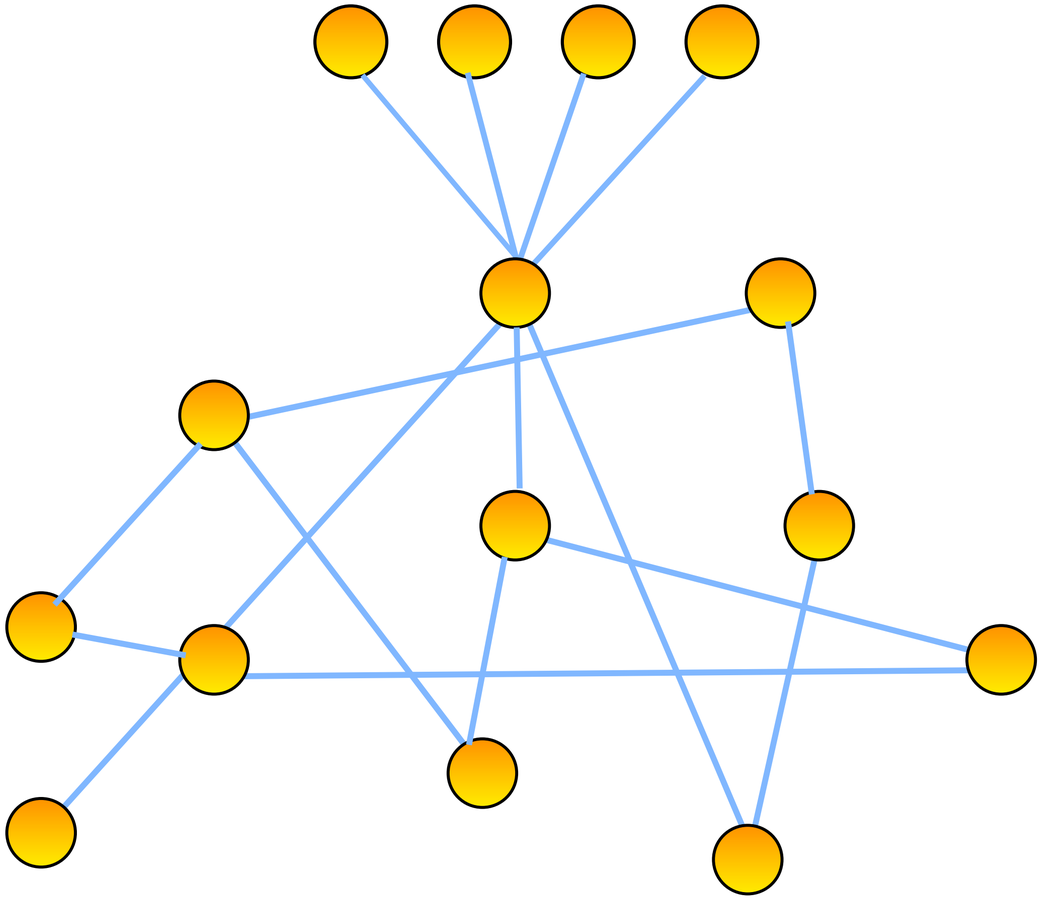
$$log\Big(P(k)\Big) = log(c) - \gamma\ log(k)$$

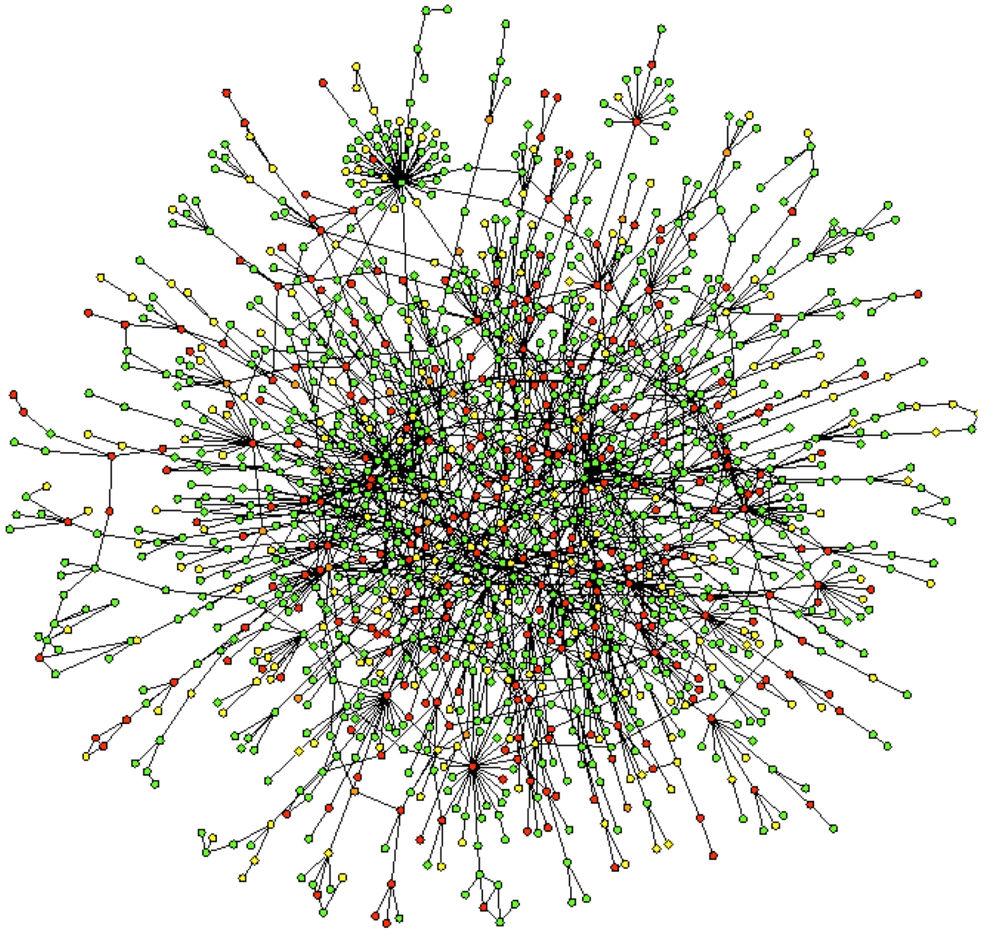
Most real networks have the same internal structure

Why?

What are the implications?

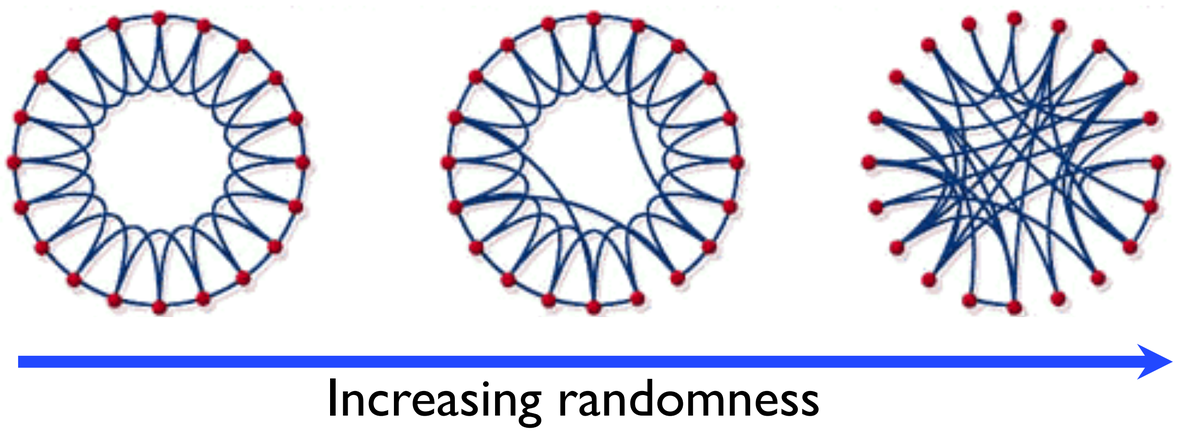
preferential attachment

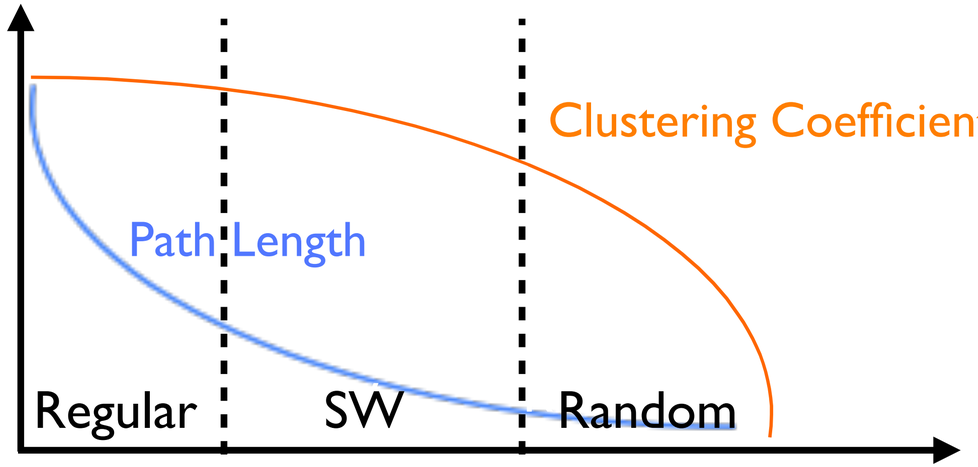




Rich get richer!

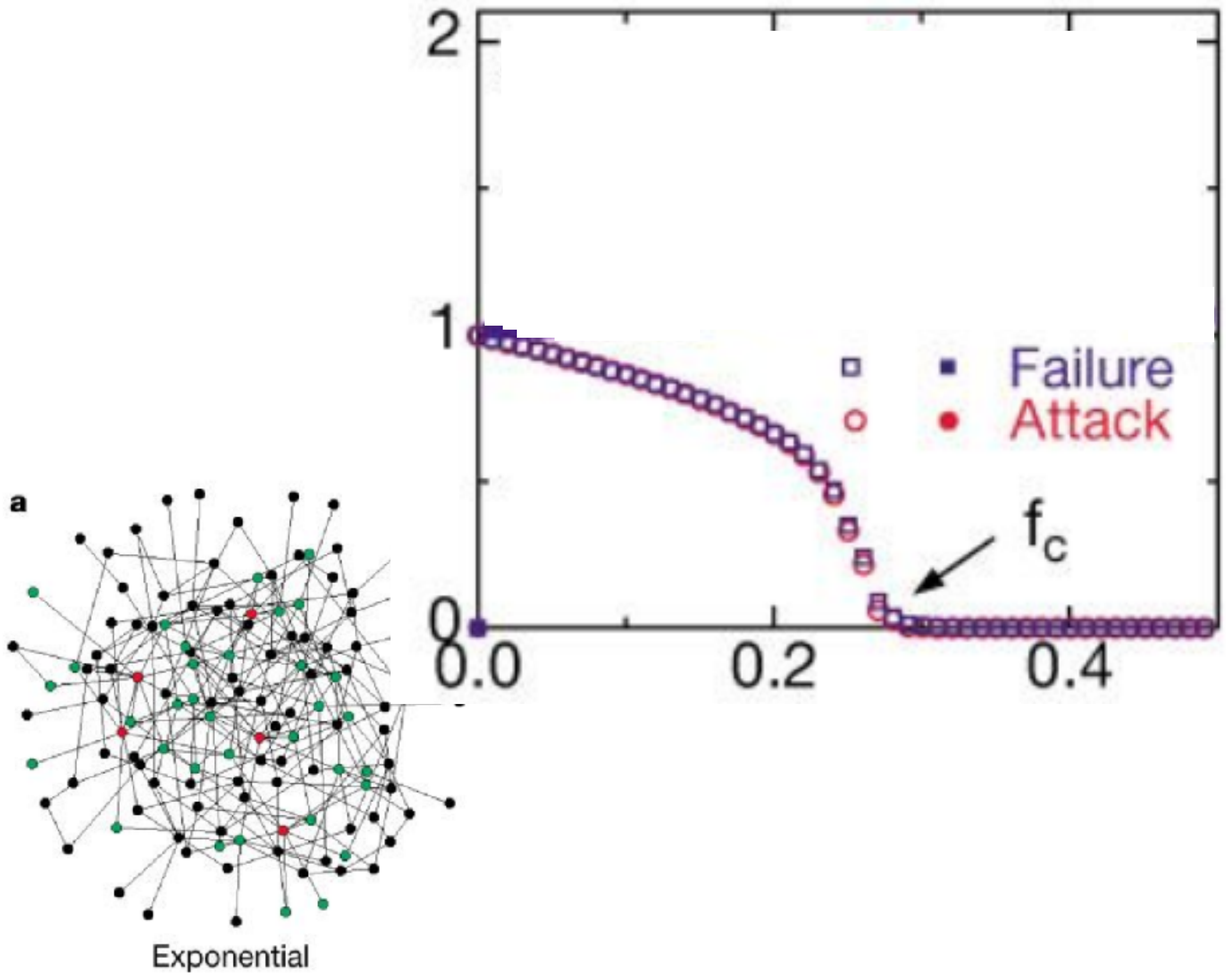
back to the small world





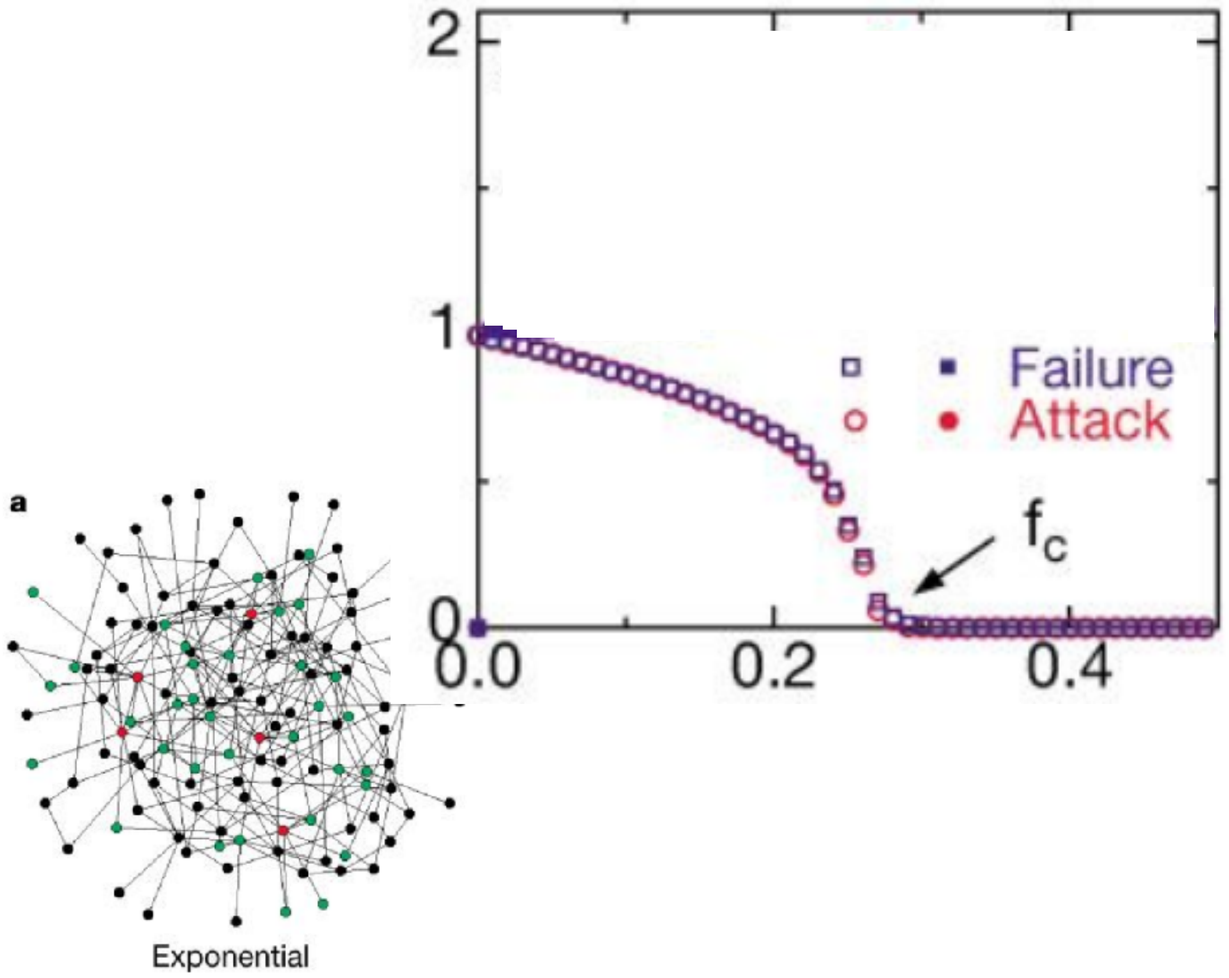
Watts and Strogatz (1998)

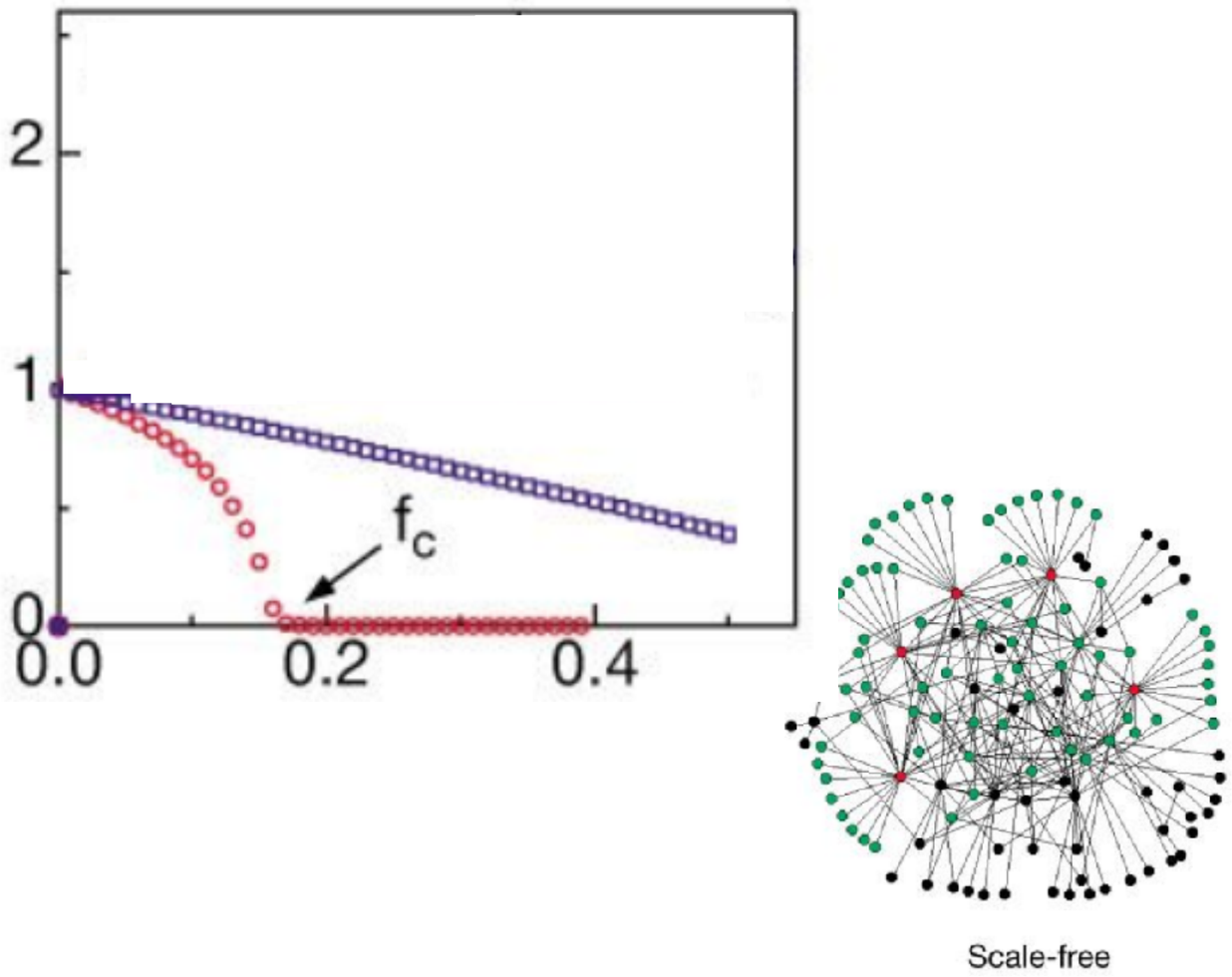
network robustness



Albert *et al.* (2000)

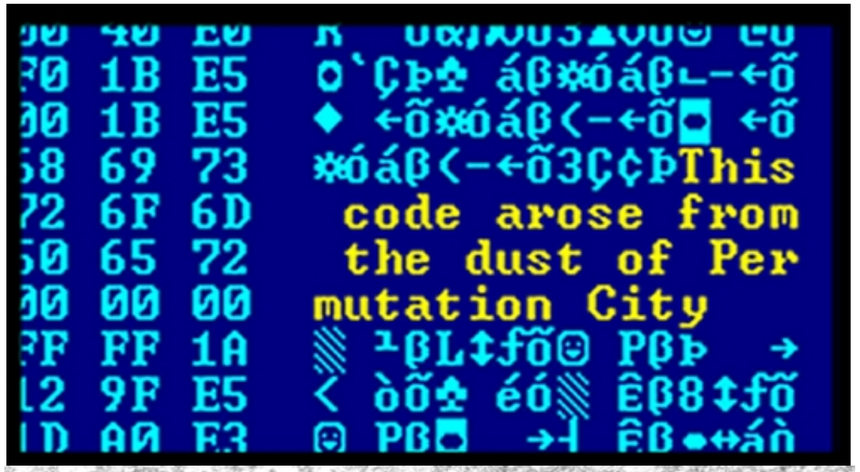
network robustness

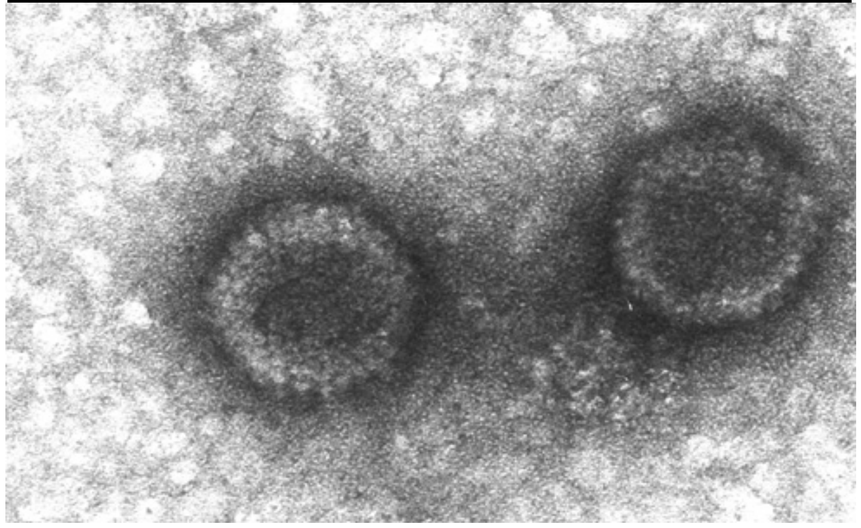




Albert *et al.* (2000)

eradication in viruses





infection rate

spreading rate

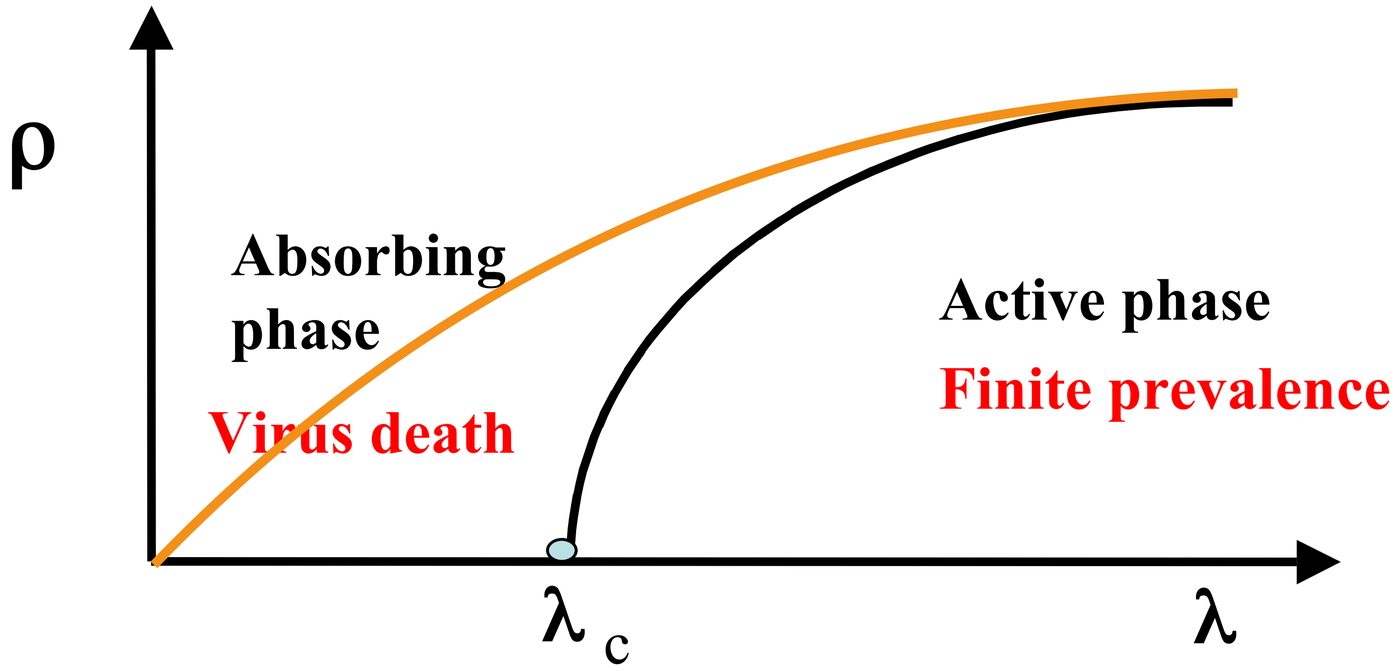
$$\lambda = \frac{\mu}{\delta}$$

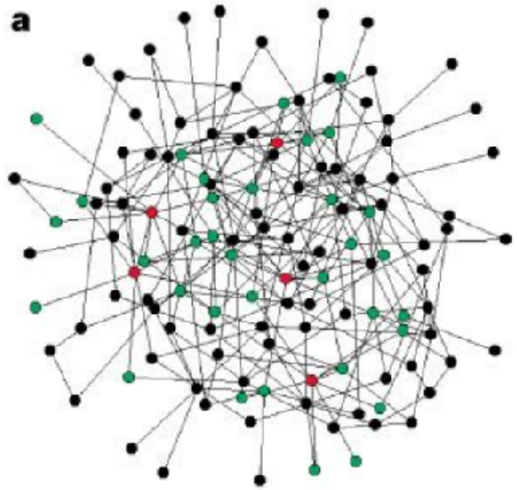
recovery rate

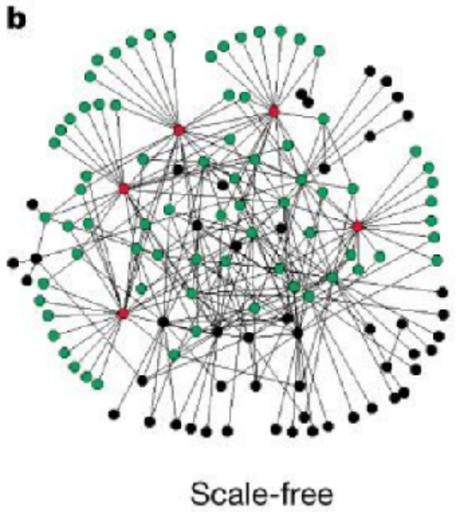
prevalence

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

eradication in viruses

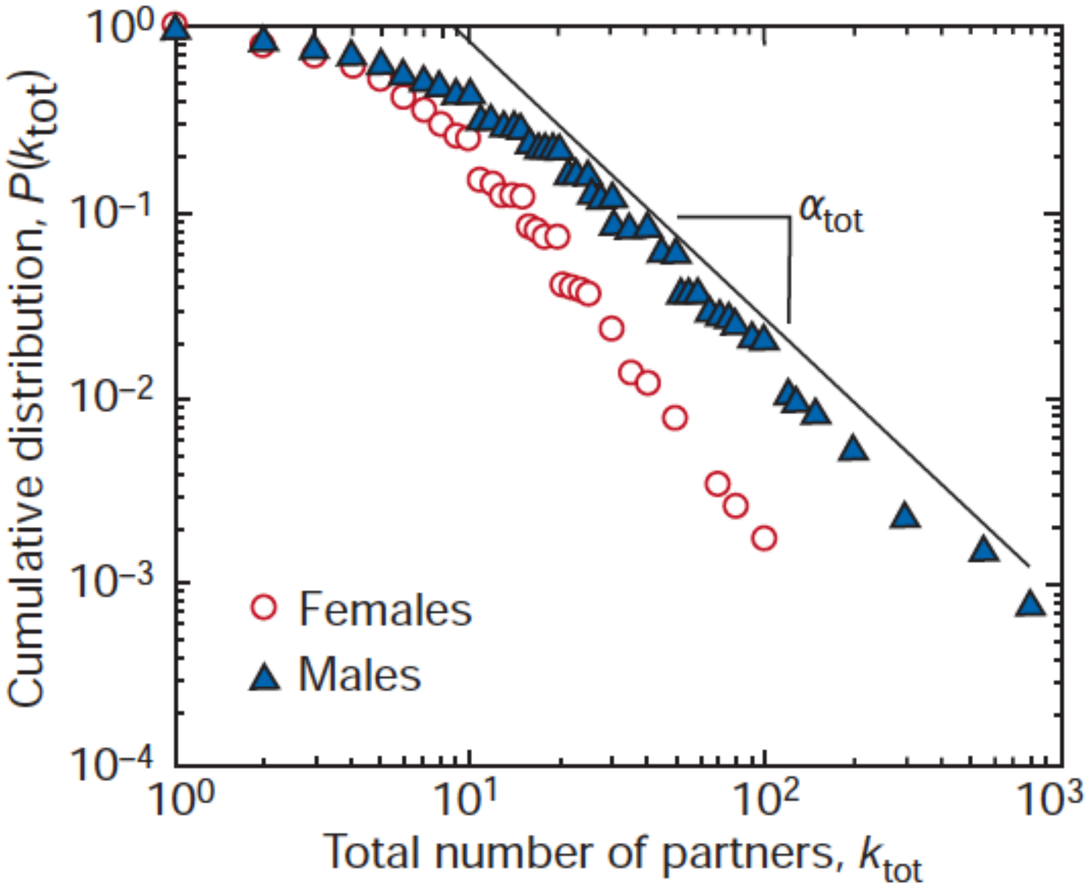


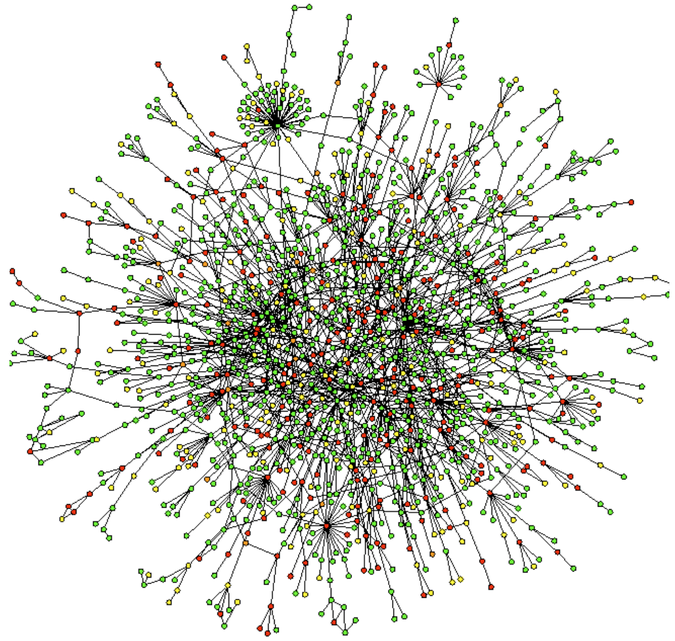




Pastor Satorras and Vespignani (2001)

sexually transmitted diseases

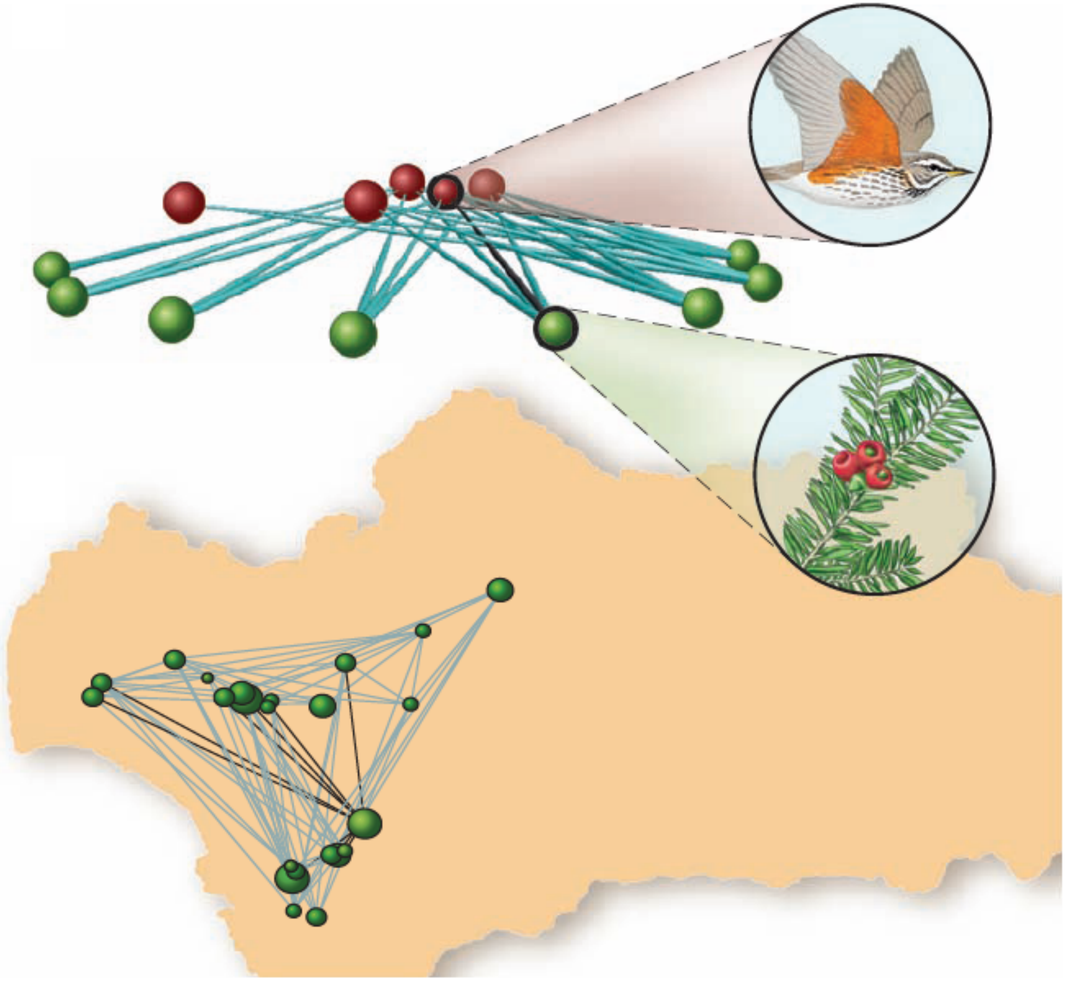




Absence of eradication thresholds in scale-free networks

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.

current/future applications of network theory

(1) Financial systems

PERSPECTIVE

doi:10.1038/nature09659

Systemic risk in banking ecosystems

Andrew G. Haldane[1] & Robert M. May[2]

In the run-up to the recent financial crisis, an increasingly elaborate set of financial instruments emerged, intended to optimize returns to individual institutions with seemingly minimal risk. Essentially no attention was given to their possible effects on the stability of the system as a whole. Drawing analogies with the dynamics of ecological food webs and with networks within which infectious diseases spread, we explore the interplay between complexity and stability in deliberately simplified models of financial networks. We suggest some policy lessons that can be drawn from such models, with the explicit aim of minimizing systemic risk.

- *"Looking at financial risk through a network lens indicates a fundamentally different rationale for prudential regulation."*
- *"In the United Kingdom, the new government have recently set up a Royal Commission to investigate the case for encouraging modularity and diversity in banking ecosystems, as a means of buttressing systemic resilience."*

www.nature.com/scientificreports

SCIENTIFIC REPORTS

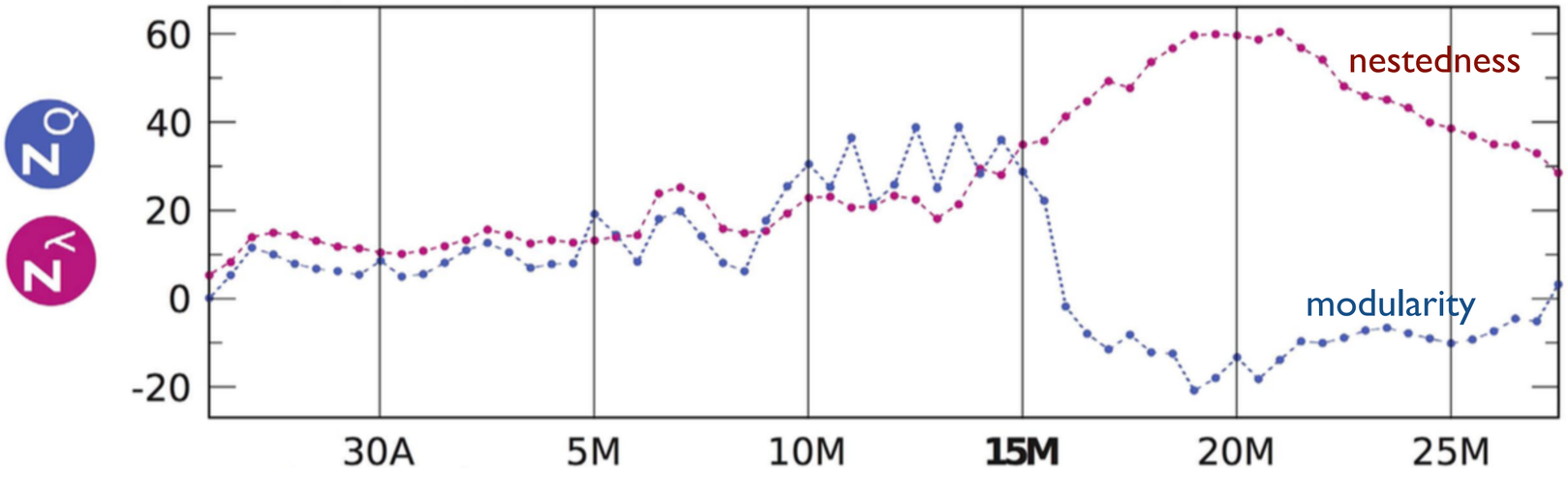
(2) Social revolts

OPEN

Emergence of consensus as a modular-to-nested transition in communication dynamics

Received: 01 March 2016
Accepted: 28 December 2016

Javier Borge-Holthoefer[1,2,3], Raquel A. Baños[3], Carlos Gracia-Lázaro[3] & Yamir Moreno[3,4,5]



"Our results show that collective attention around a topic is reached when the user-meme network self- adapts from a modular to a nested structure, which ultimately allows minimizing competition and attaining consensus."

Wjst et al. Genome Medicine (2018) 10:96
https://doi.org/10.1186/s13073-018-0608-4

Genome Medicine

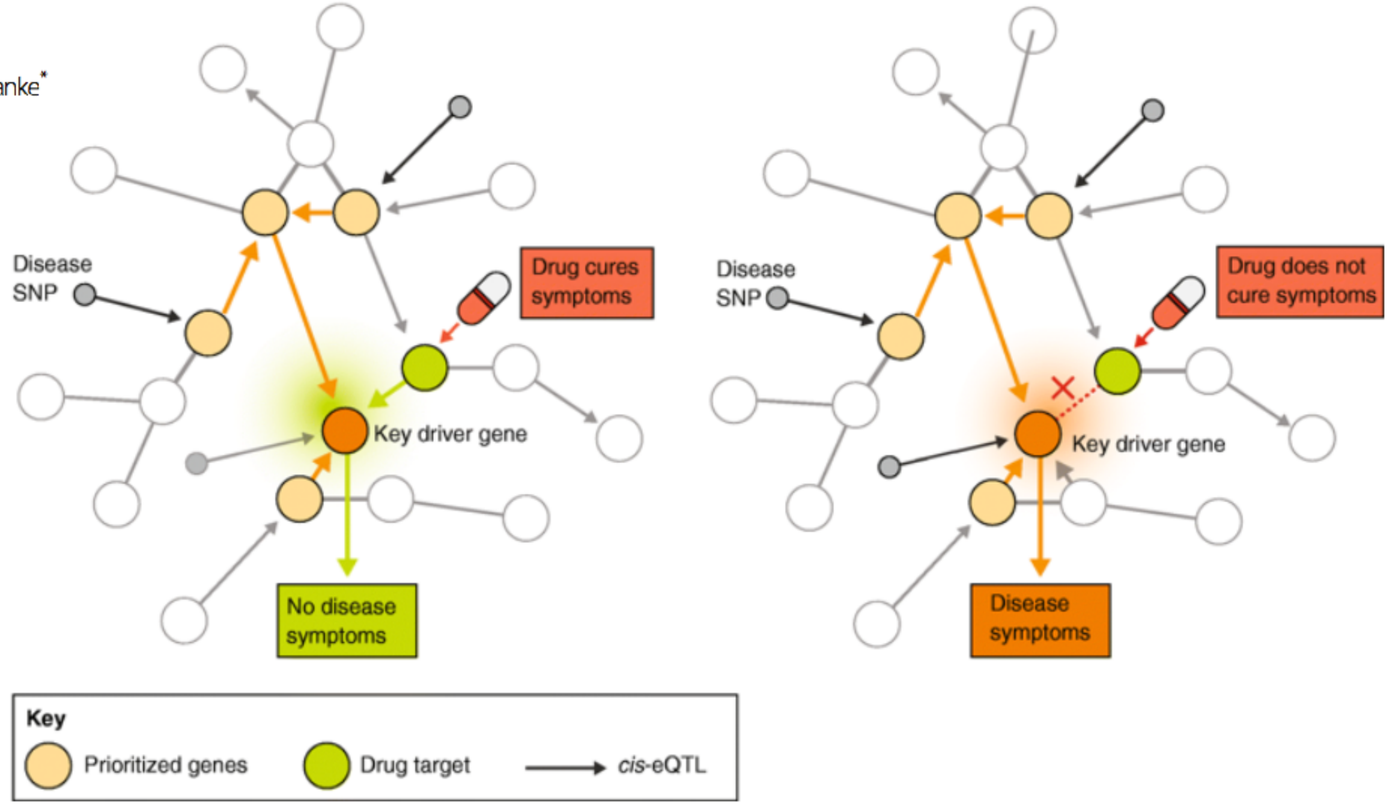
OPINION Open Access

An integrative approach for building personalized gene regulatory networks for precision medicine

Monique G. P. van der Wijst†, Dylan H. de Vries†, Harm Brugge, Harm-Jan Westra and Lude Franke*

(3) Personalized medicine

inter-individual variation in drug response driven by differences in each patient's gene regulatory networks



the drug target gene activates the key driver gene

interaction between the drug target gene and the key driver gene is absent