Σύνθετα Δίκτυα

Διδάσκων –
Δημήτριος Κατσαρός

Εισαγωγή στα Σύνθετα Δίκτυα

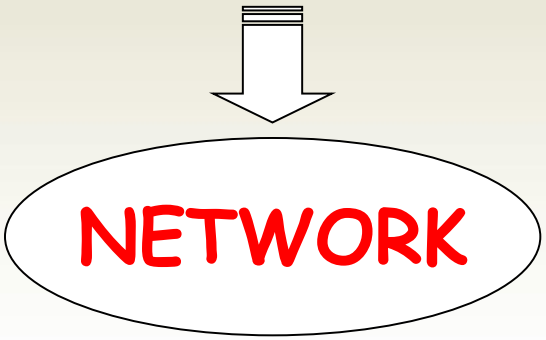
2021 Nobel Prize in Physics

for groundbreaking contributions
to our understanding of
complex physical systems',

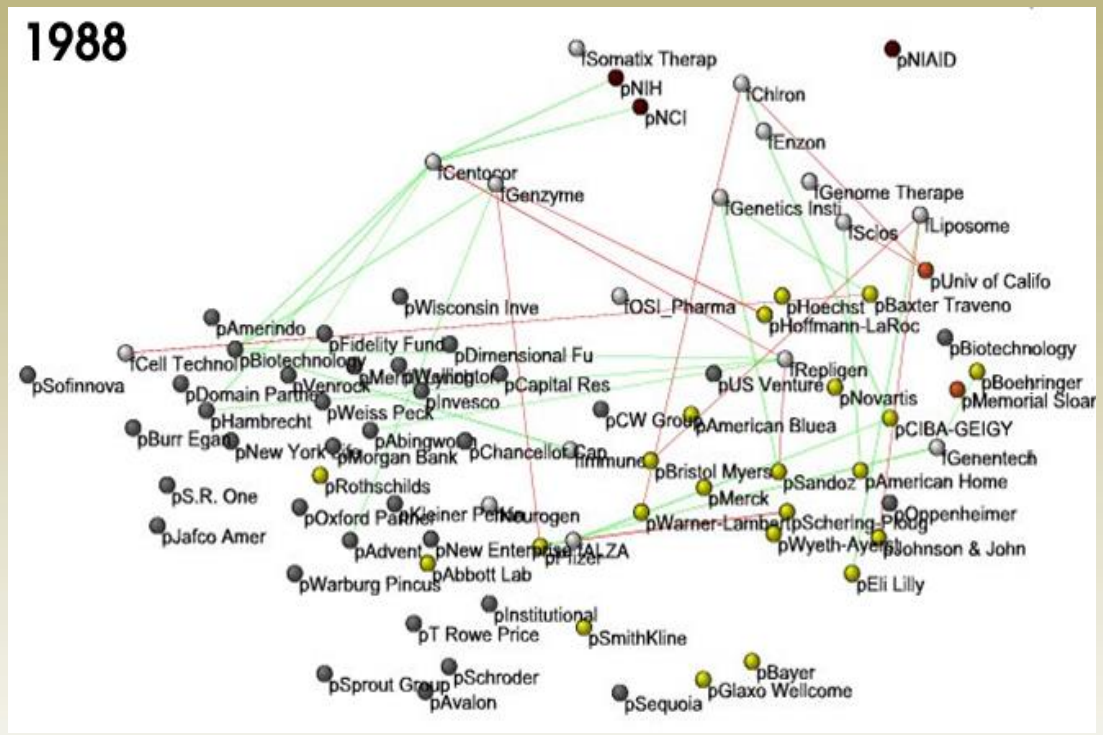
with half going to
Giorgio Parisi
'*for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales*'

Complex systems

Made of
many non-identical **elements**
connected by diverse **interactions**.



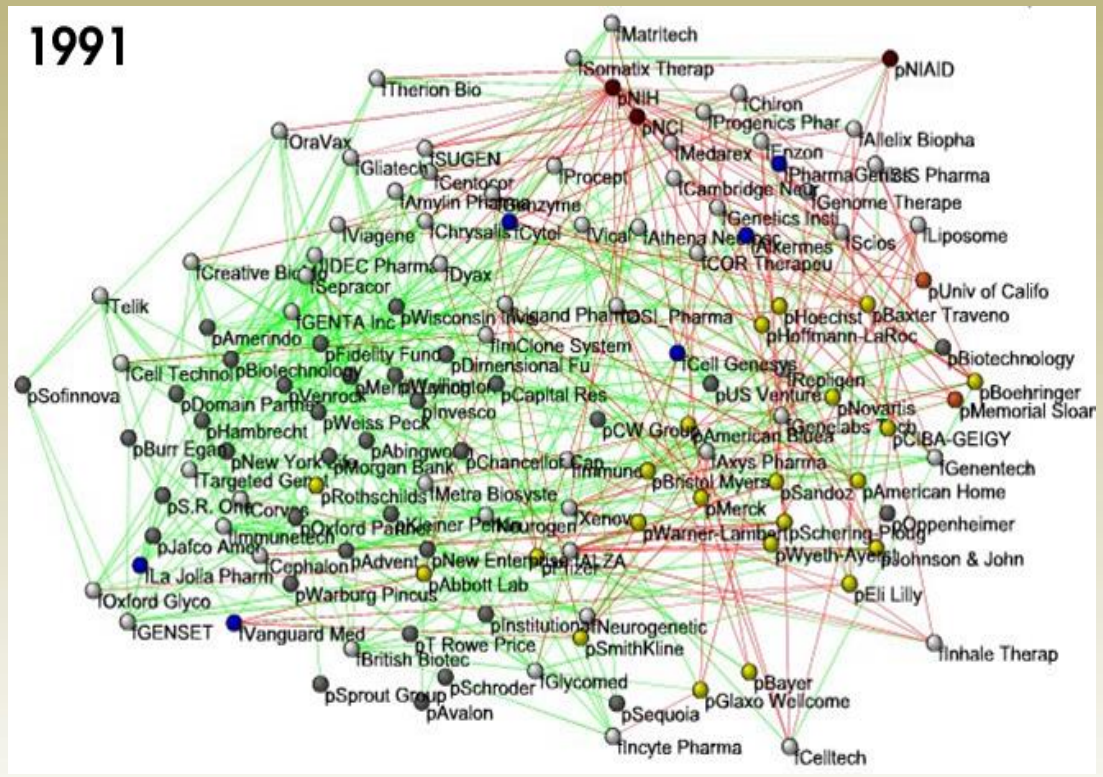
Business ties in US biotech-industry



Nodes: companies: investment
pharma
research labs
public
biotechnology

Links: financial
R&D collaborations

Business ties in US biotech-industry



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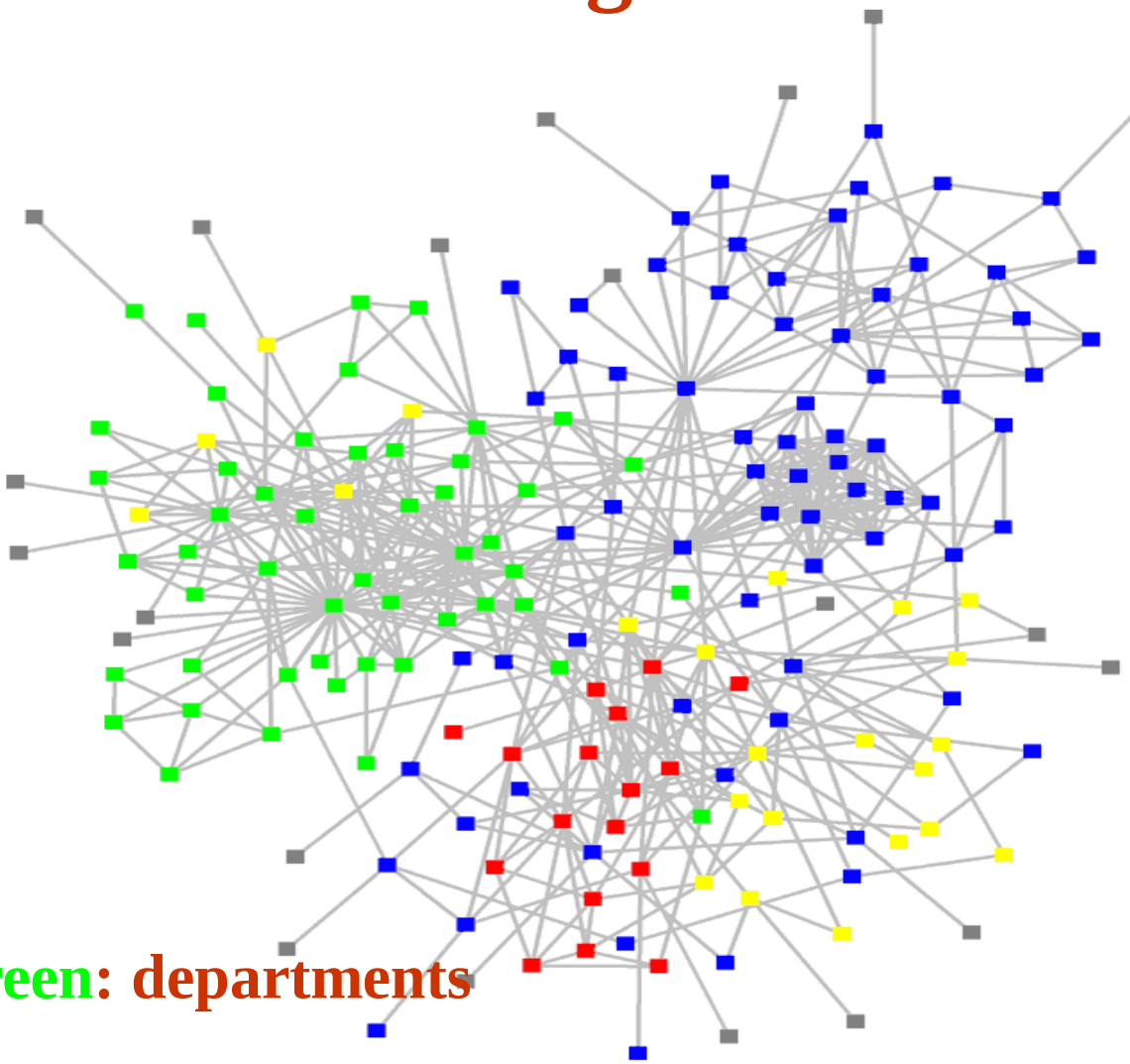
Structure of an organization

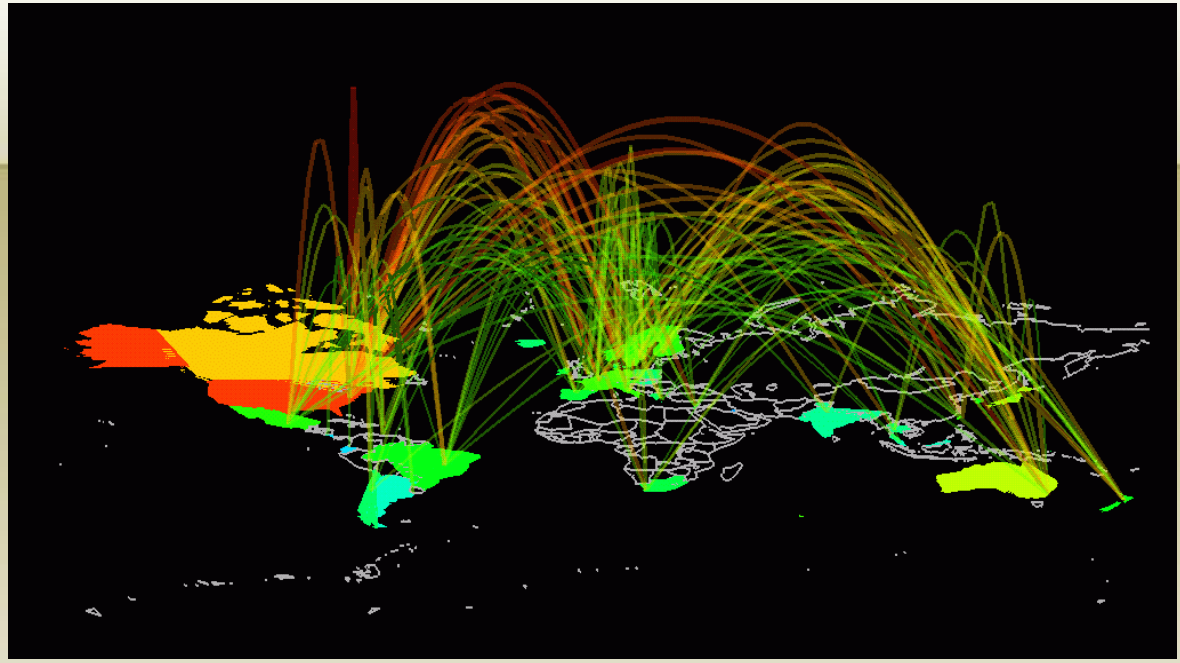


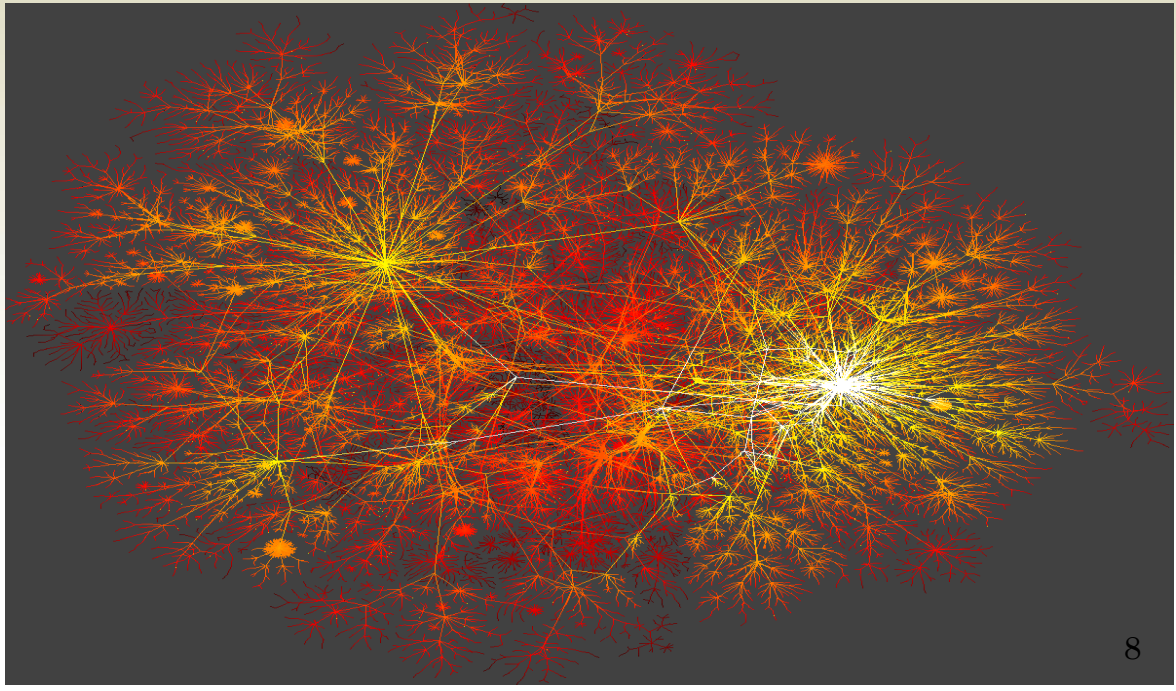
Red, blue, or green: departments

Yellow: consultants

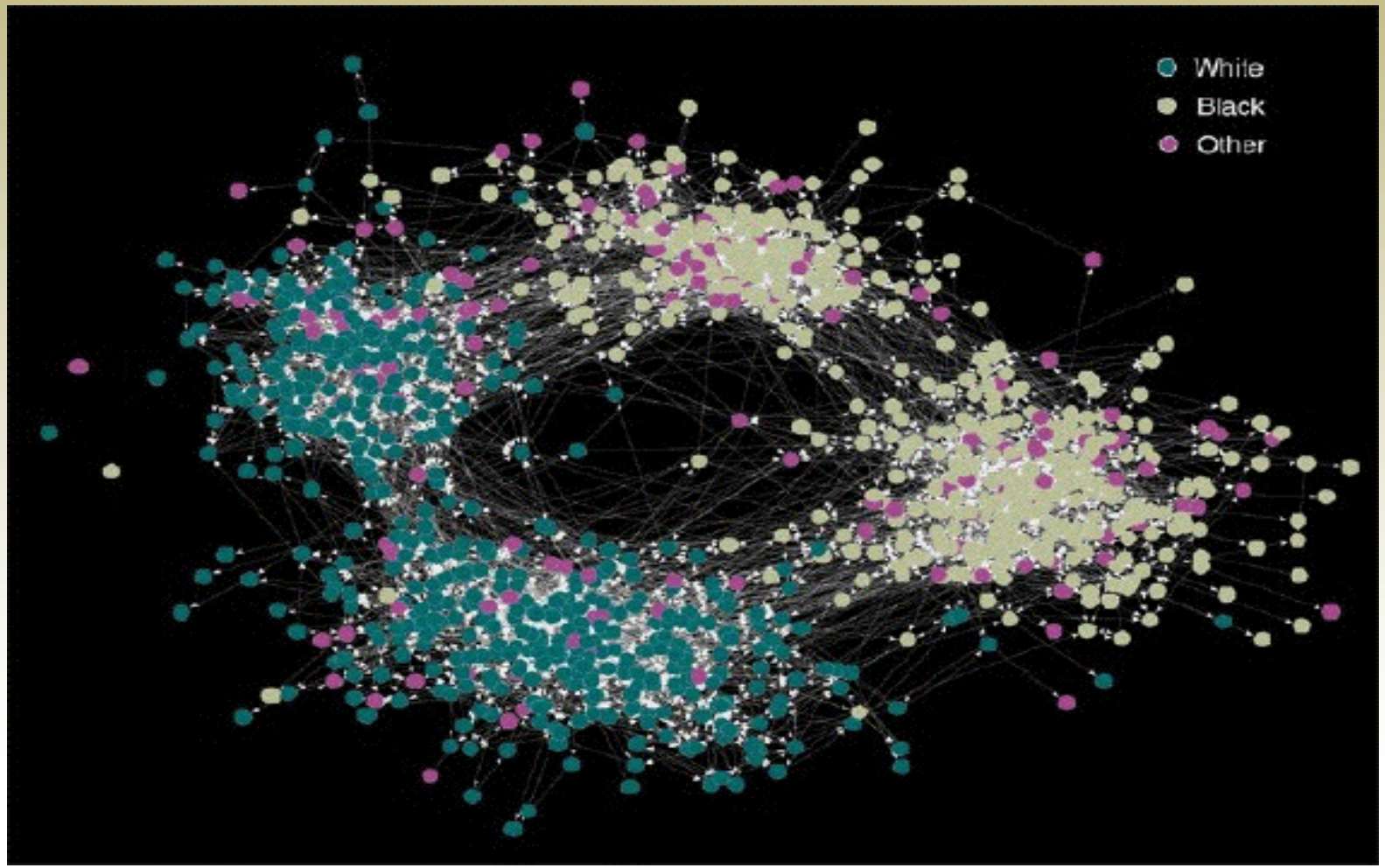
Grey: external experts

Internet

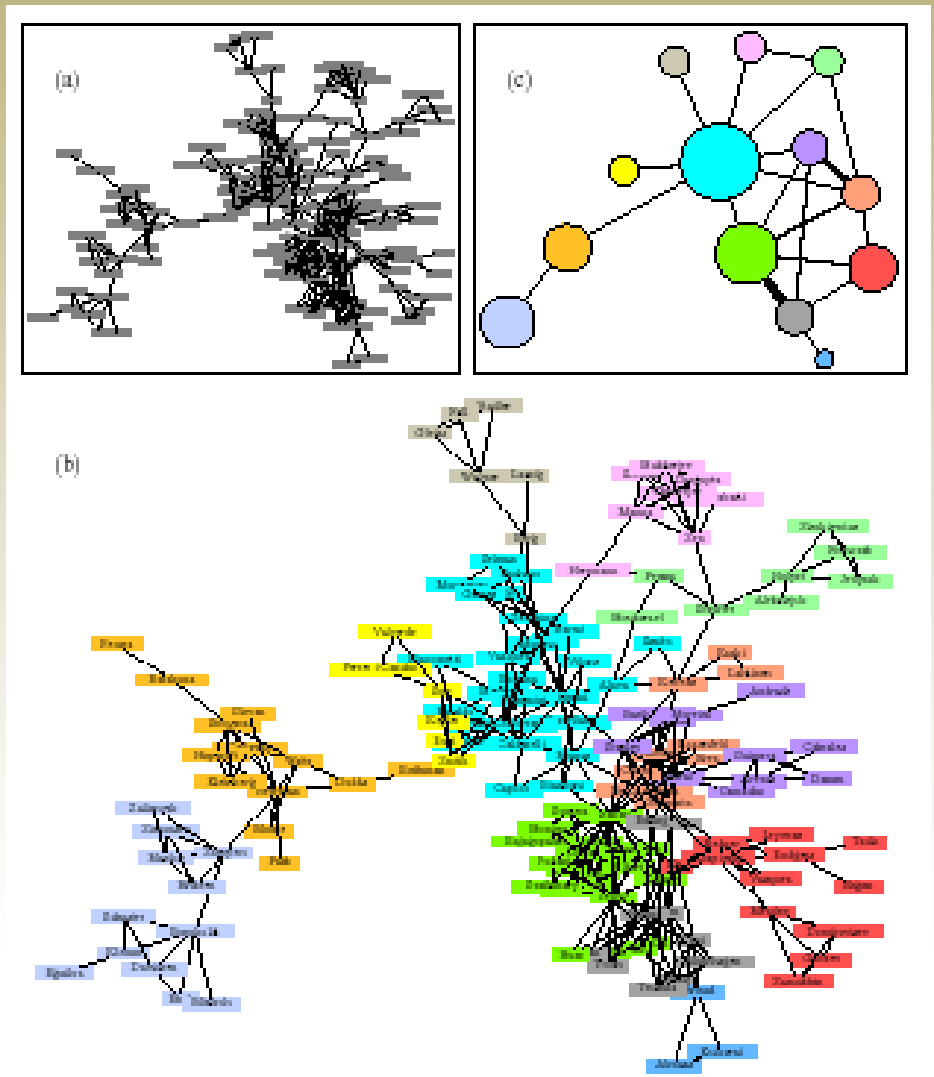




Friendship Network



Network Collaboration Network



9-11 Terrorist (?) Network

Social Network Analysis is a mathematical methodology for *connecting the dots* -- using science to fight terrorism. Connecting multiple pairs of dots soon reveals an emergent *network* of organization.

Swedish sex-web

Nodes: people (Females; Males)

Links: sexual relationships

4781 Swedes; 18-74;
59% response rate.

Liljeros et al. *Nature* 2001

Road and Airlines Network

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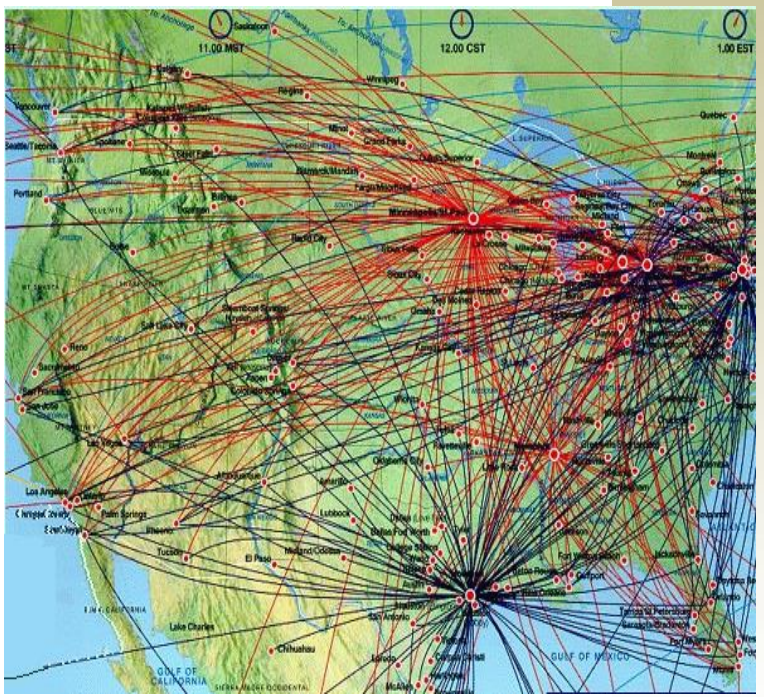

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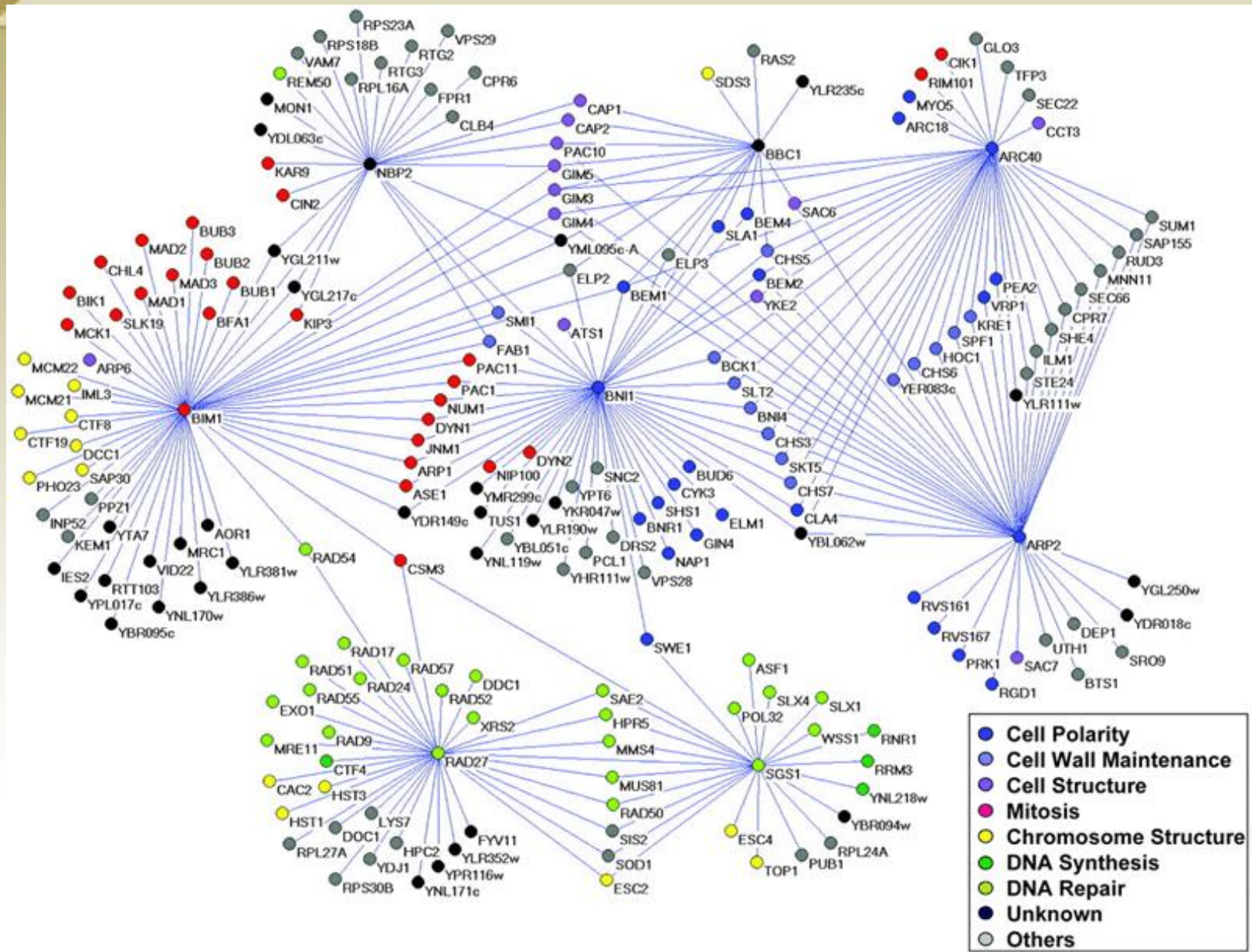
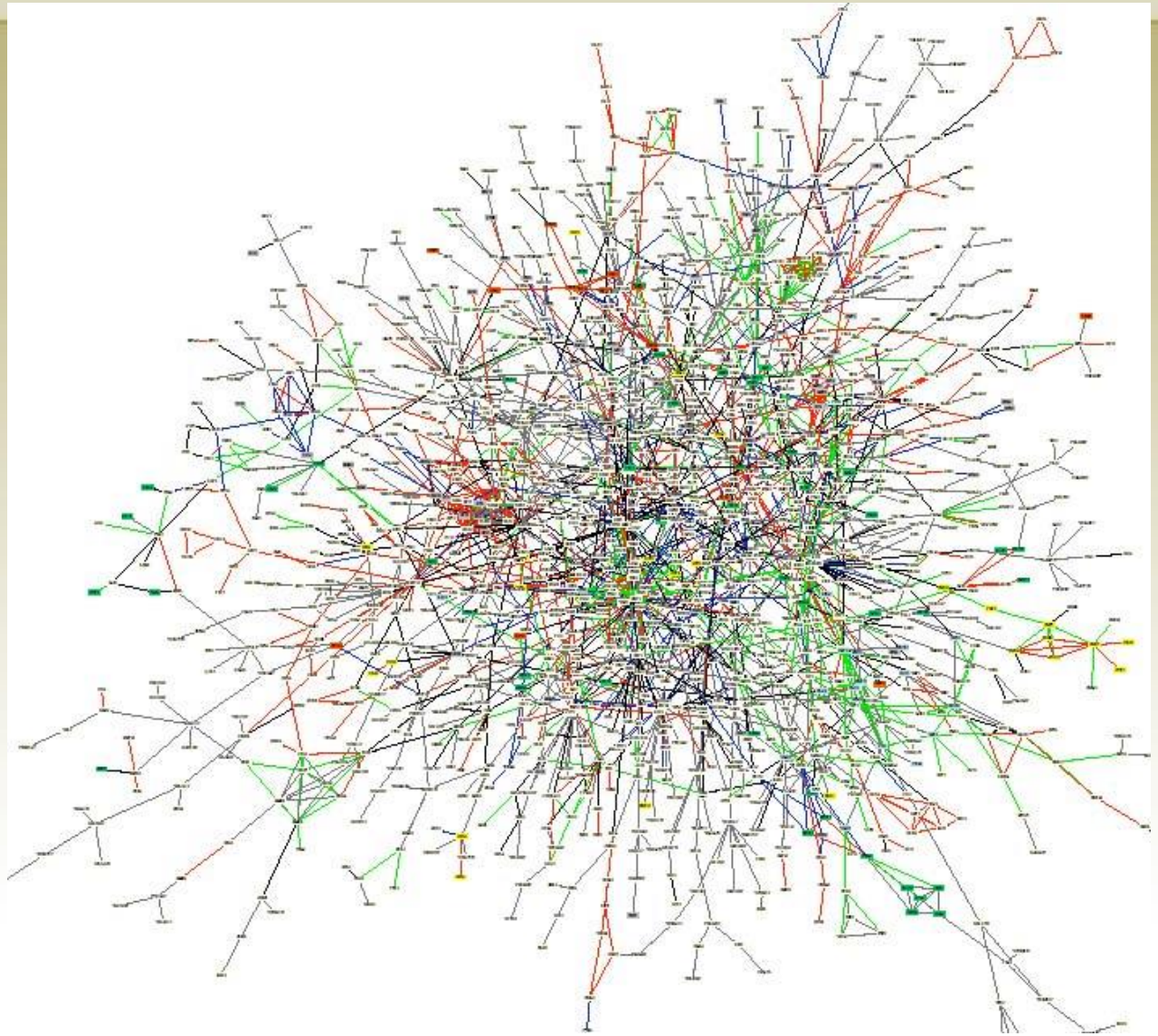
Genetic interaction network



Yeast protein-protein interaction network



What Questions can be asked

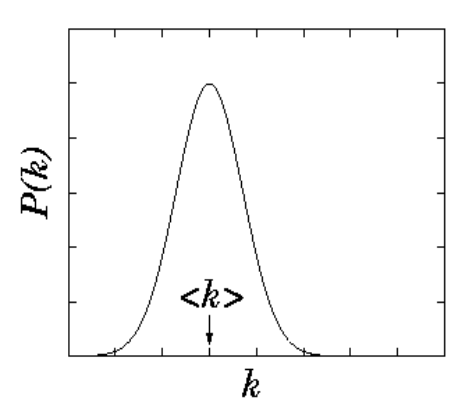
- Does these networks display some symmetry
- Are these networks creation of intelligent objects or they have emerged.
- How have these networks emerged
    - Underlying simple rules leading to their complex formation

What Questions can be asked

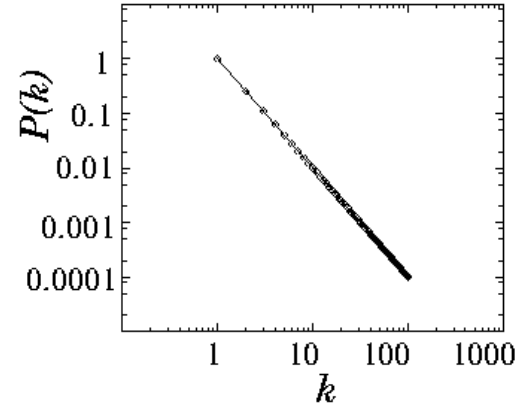
- Can we predict some outcomes/ make statements about the health of the system represented by the network
- Are these networks robust against failure
- Does these networks help in information flow
- How can we engineer (build) such network, (engineering complex systems).

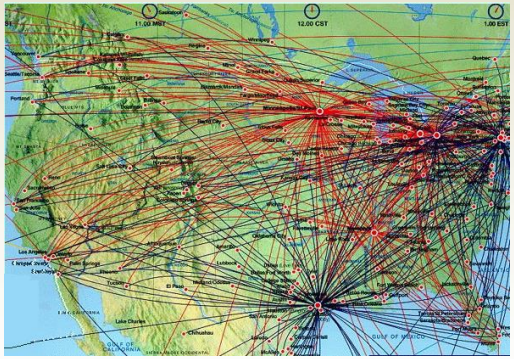
Symmetry

Poisson distribution



Power-law distribution

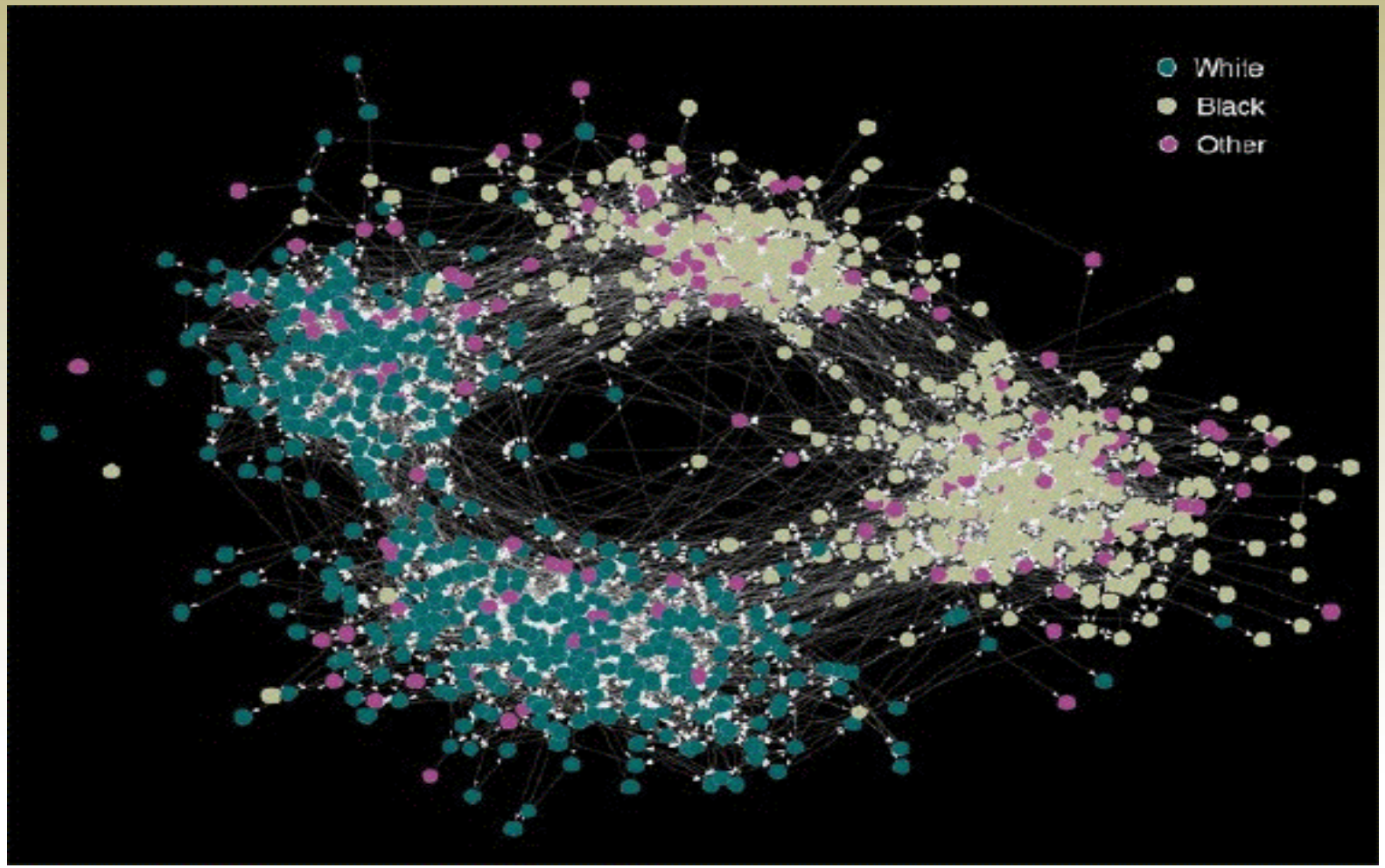




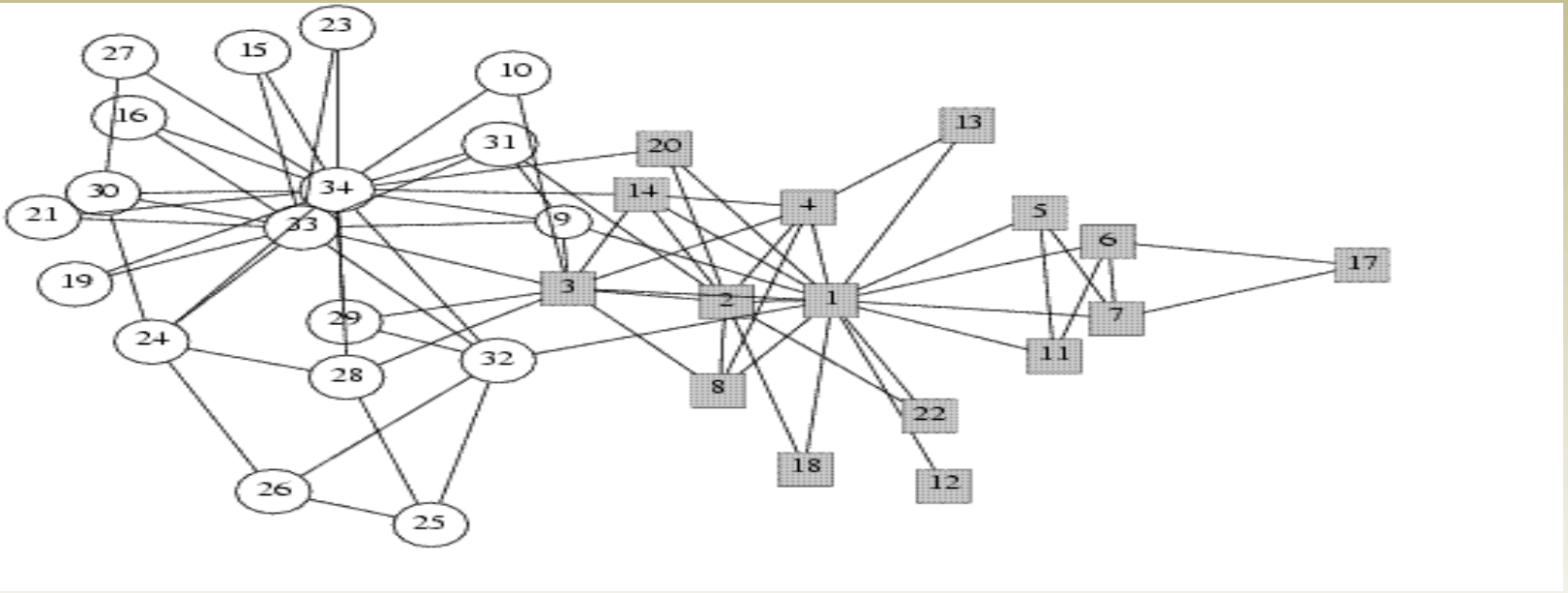
Exponential Network

Scale free Network

Friendship Network (Community)



Karate Club



Instructors 1 and 33

The Small World Effect

How do human contact patterns influence the spread of disease?

Outbreaks of SARS (Severe Acute Respiratory Syndrome)

The Small World Effect

Even in very large social networks, the average distance between nodes is usually quite short.

Milgram's small world experiment:

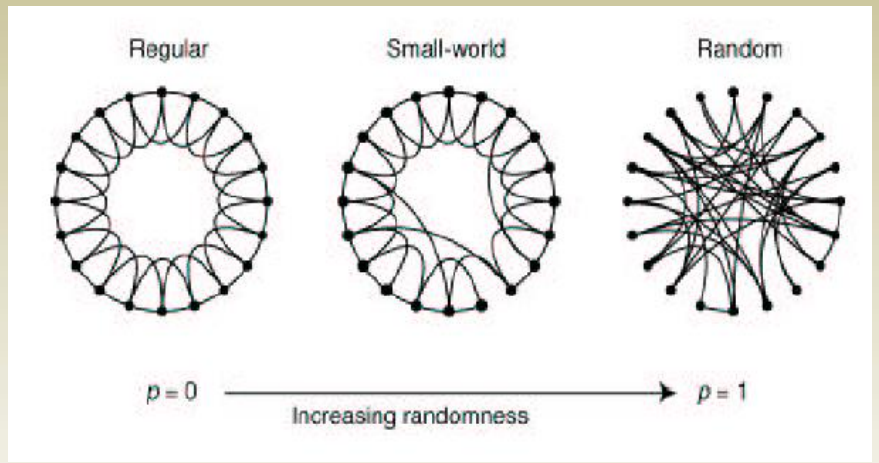
- Target individual in Boston
- Initial senders in Omaha, Nebraska
- Each sender was asked to forward a packet to a friend who was closer to the target
- Friends asked to do the same

Result: Average of 'six degrees' of separation.

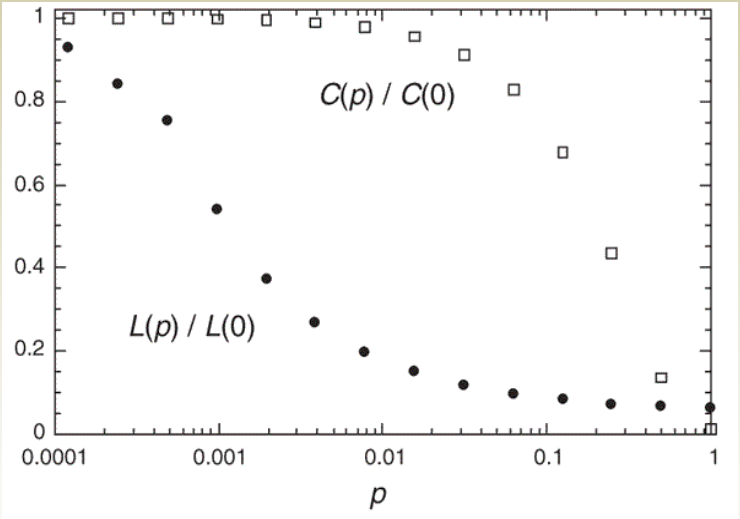
S. Milgram, *The small world problem,* Psych. Today, 2 (1967), pp. 60-67.

Watts-Strogatz 'Small World' Model (Simple Rules)

Watts and Strogatz introduced this simple model to show how networks can have both short path lengths and high clustering.



QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.



D. J. Watts and S. H. Strogatz, *Collective dynamics of "small-world" networks*, Nature, 393 (1998), pp. 440–442.

Swedish sex-web

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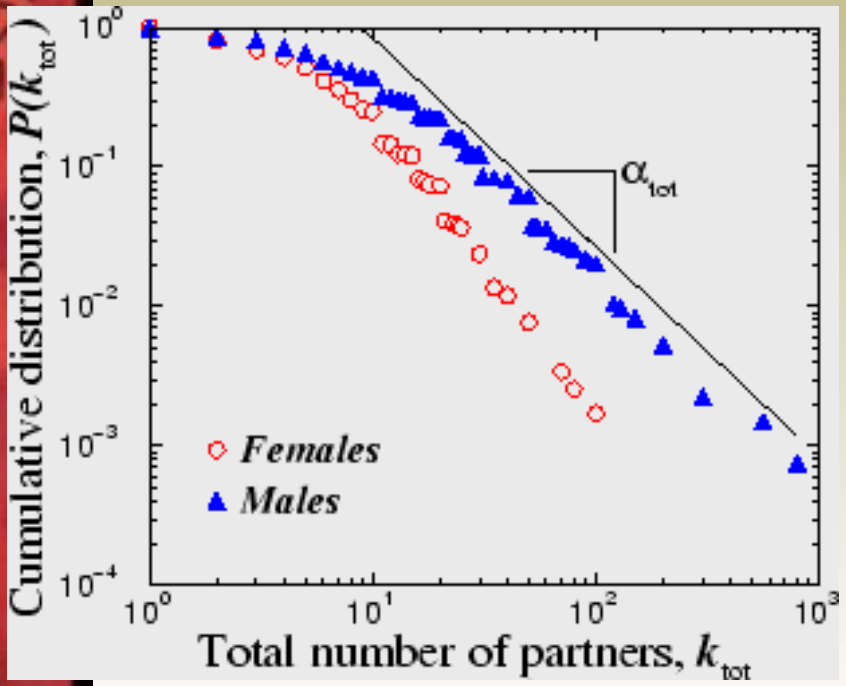
Links: sexual relationships



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Internet

- Robust against random failure
- Vulnerable against attack

9-11 Terrorist (?) Network

How to conduct investigation

Some interesting Problems

- Consonants (Language) Networks
- Marriage Networks
- Collaboration Networks
- Build Networks which are robust as well as efficient
- Actors Network

Course Outline

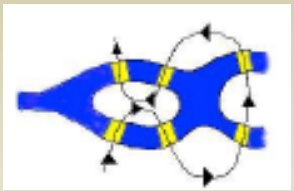
- Techniques to analyze networks
- Special types of networks – random networks, power law networks, small world networks
- Models of network growth
- Processes taking place on network – search, epidemics
- Centralities, communities, influentials

Traditional vs. Complex Systems Approaches to Networks

Traditional Questions:

Social Networks:
Who is the most important person in the network?

Graph Theory:
Does there exist a cycle through the network that uses each edge exactly once?



Complex Systems Questions:

What fraction of edges have to be removed to disconnect the graph?

What kinds of structures emerge from simple growth rules?