

Complex Networks (CS60078)

Instructor: Animesh Mukherjee

TAs: Tanmoy Chakraborty

Swadhin Pradhan

Course Directives

- Time (hrs): Monday 11:30 - 12:25, Tuesday 9:30 – 11:25
- Extra classes (if reqd.): Thursday 7:30 - 8:30
- Room: CSE 119
- Webpage:
http://cse.iitkgp.ac.in/~animeshm/course_cnt2014.html
- Marks:
 - Midterm: 20%
 - Term project: 30%
 - Attendance & class performance: 10%
 - Blog: 5%
 - Endterm: 35%

Blogging ...



- Name: **Homophily**
- Typically of the type of power-law (<http://complexnt.blogspot.com/>) and six-degrees (<http://cnt13.blogspot.in/>)
- No summary of the class lecture!
- What exactly then:
 - One person each day tries to gather something interesting (in the form of a short summary possibly associated with one figure) and possibly unknown to most of us in this area of research (could be something very old or very contemporary)
 - Others read, comment and discuss on the posted topic
 - You might also post relevant announcements (call for papers, call for participation in summer schools etc. each time explaining why you found it relevant)

Term project ...

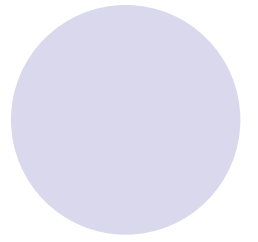
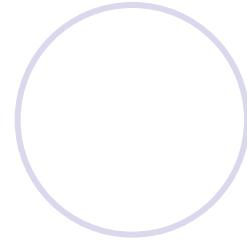
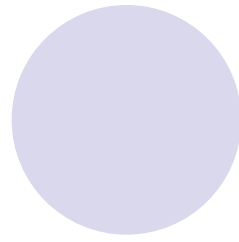
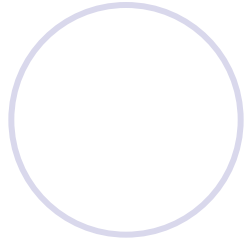
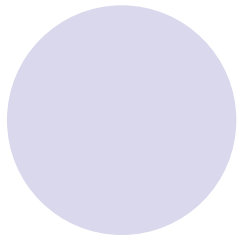


A mini project (topics will be soon circulated).

- (i) Meet your mentor and understand the project,
- (ii) gather data (if reqd.),
- (iii) model/analyze/frame and solve eqns.,
- (iv) prepare presentation and tech report
(can lead to a paper)
- (v) Two evaluations: one before midsem and one before endsem

References

- *Networks: An Introduction*, Oxford University Press, Oxford, 2010. (I shall mostly follow this one)
- *Evolution of Networks*, Oxford University Press, Oxford, 2003.
- The structure and function of complex networks, *SIAM Review* **45**, 167-256, 2003.
- Statistical mechanics of complex networks, *Rev. Mod. Phys.*, **74**(1), 2002.
- Further references can be found on the course page of Dr. Niloy Ganguly (facweb.iitkgp.ernet.in/~niloy/)



Introduction

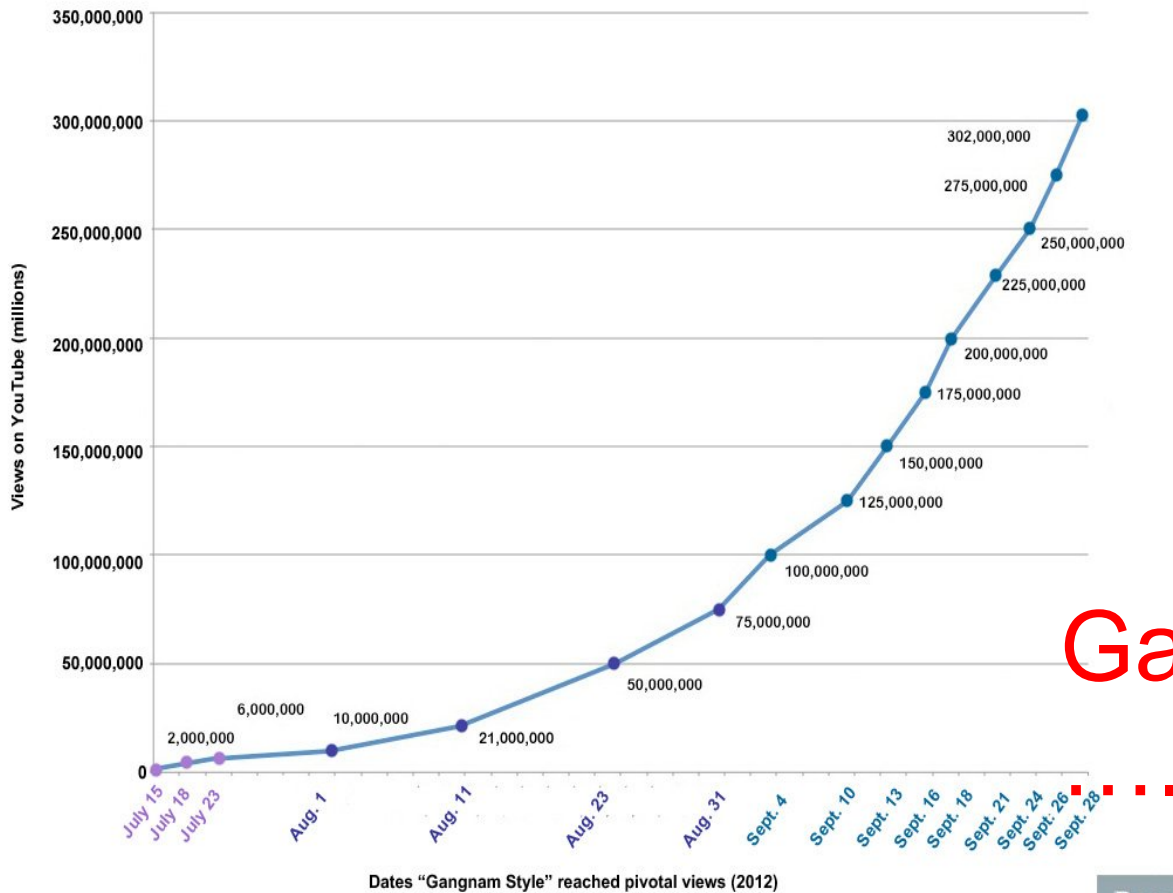
Mother father gentleman!!!

Mother father gentleman!



Mother father gentleman

Growth of 'Gangnam Style' Views On YouTube



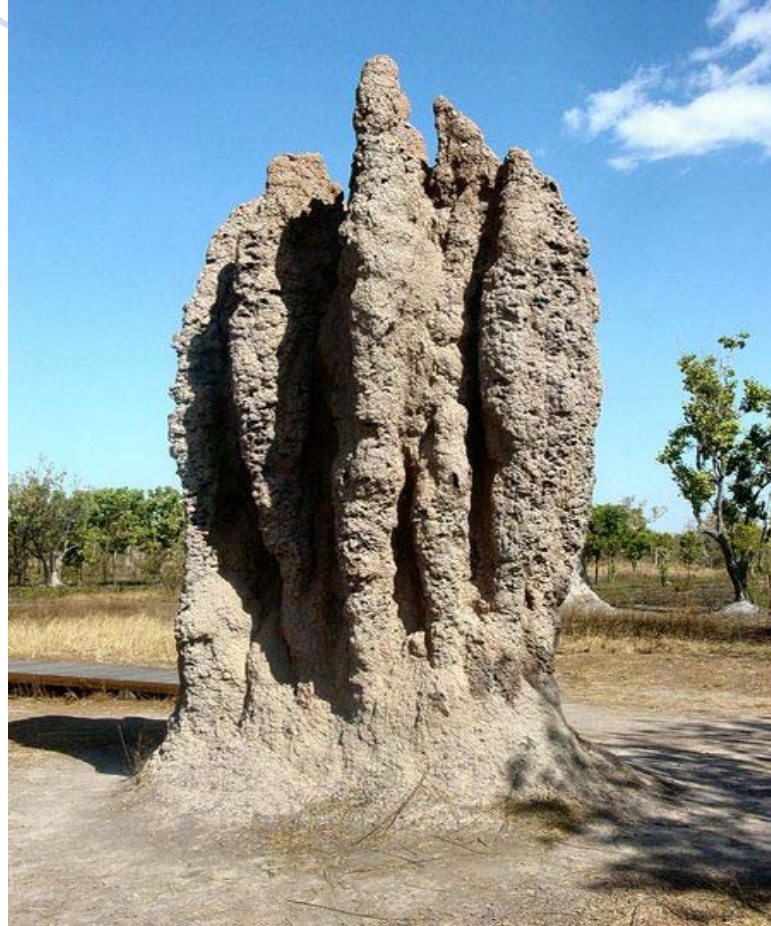
Dates "Gangnam Style" reached pivotal views (2012)



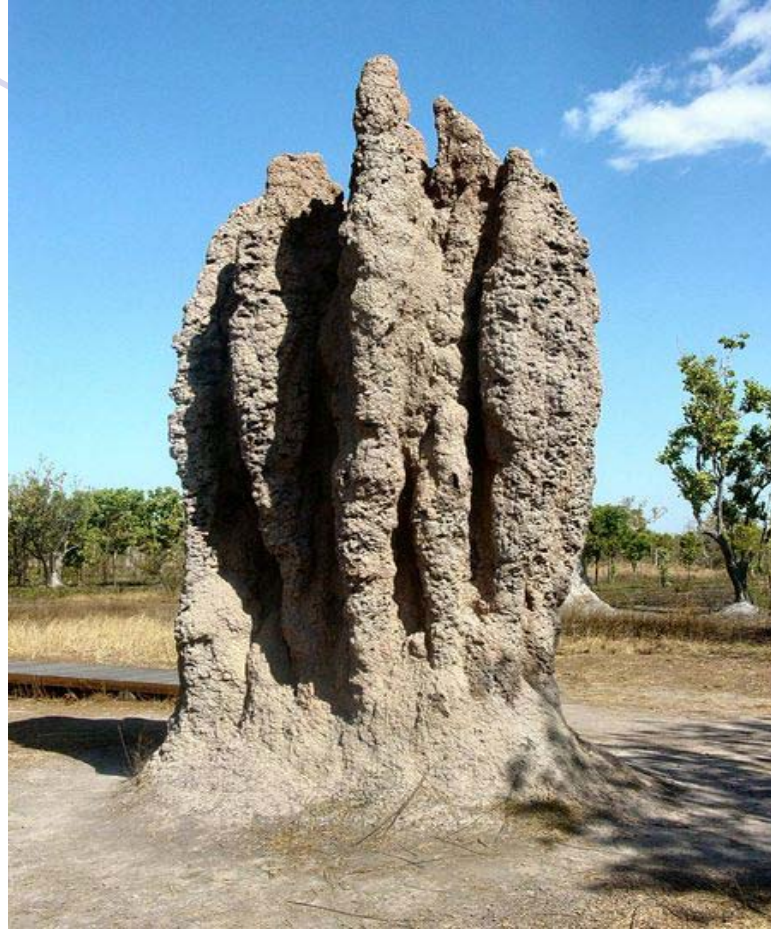
Gangnam Style

BUSINESS
INSIDER

Complexity in nature



Complexity in nature



A termite "cathedral" mound produced by a termite colony --> no engineer planned this for them!!!



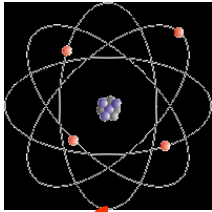
Emergence : What is it?

- *Emergence* resembles the development of a complex organized system
- It refers to the arising of novel & coherent structures, patterns & properties due to the *self-organization* going on in various complex systems
- Self-organization is a process by which a system increases its complexity through *internal re-organization* without being guided by any external source

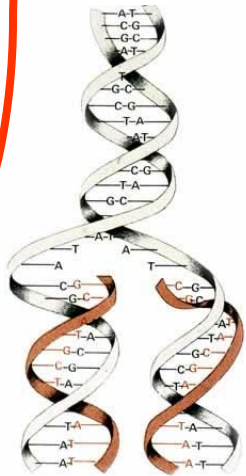
Emergence of networked life

Communities

Atom



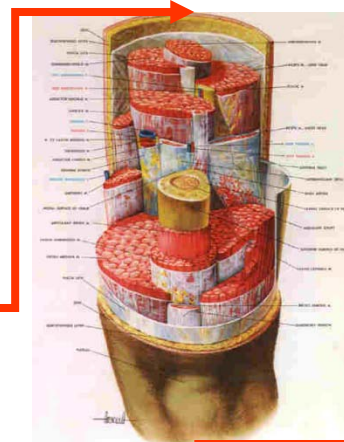
Molecule



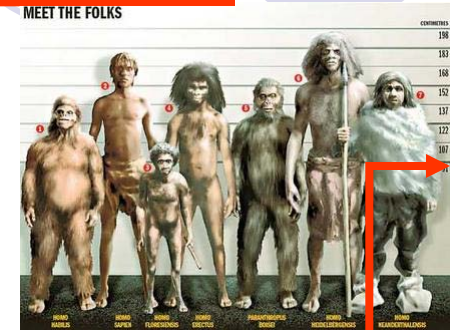
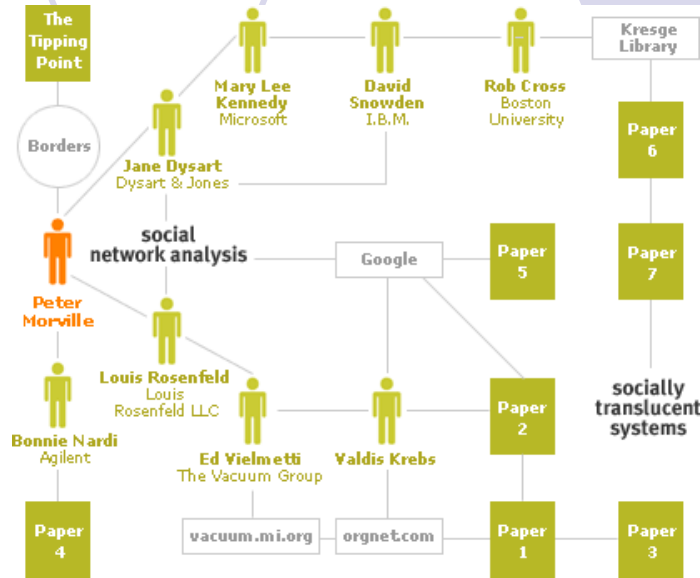
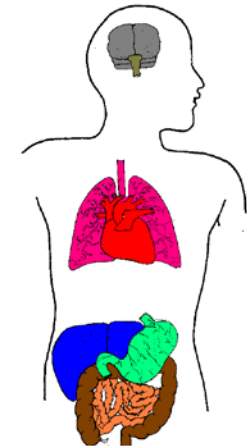
Cell



Tissue

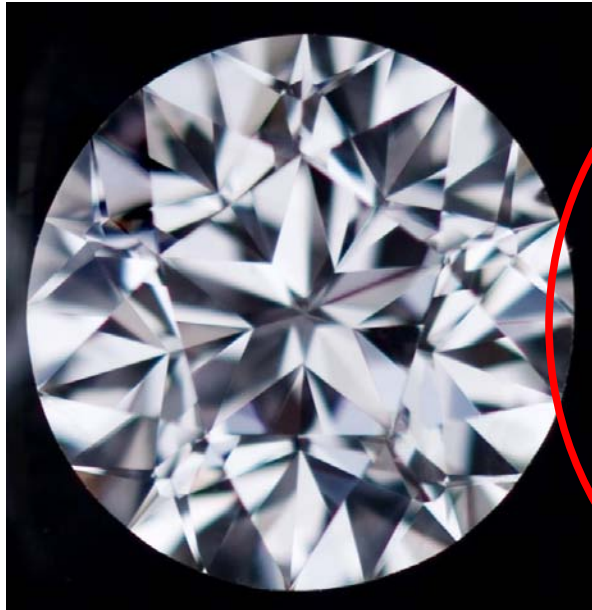


Organs



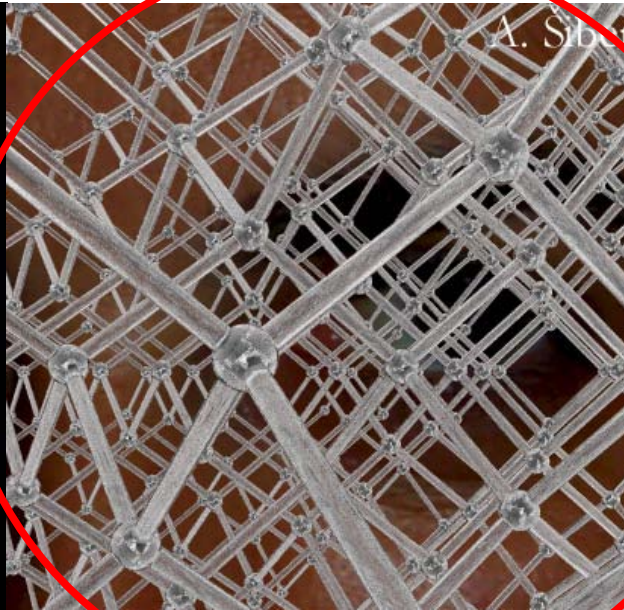
Organisms

Three Views of a System



MACROSCOPY

May not give a complete picture or explanation of what goes on

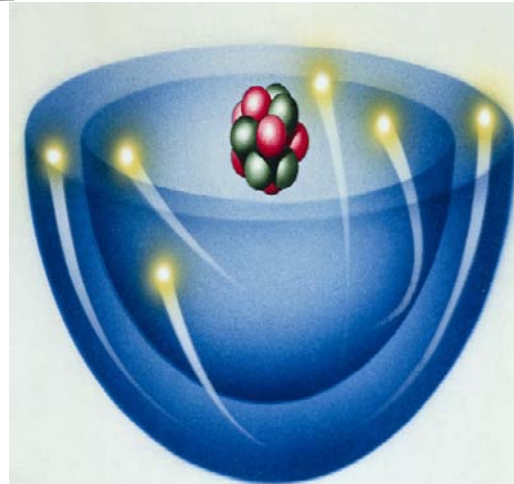


MESOSCOPY

A useful trade-off between the two

MICROSCOPY

May be too difficult to analyze or simulate the macroscopic behavior



Now coming to networks

Complex systems

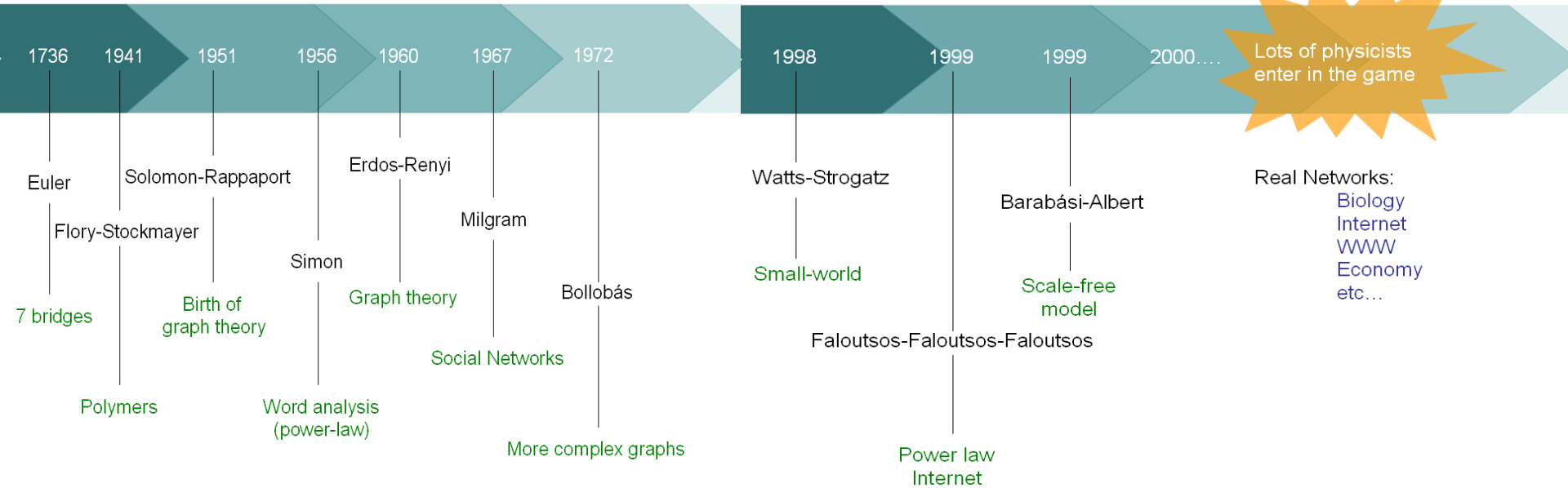
Conception

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

Formulation

NETWORK

Historical Background



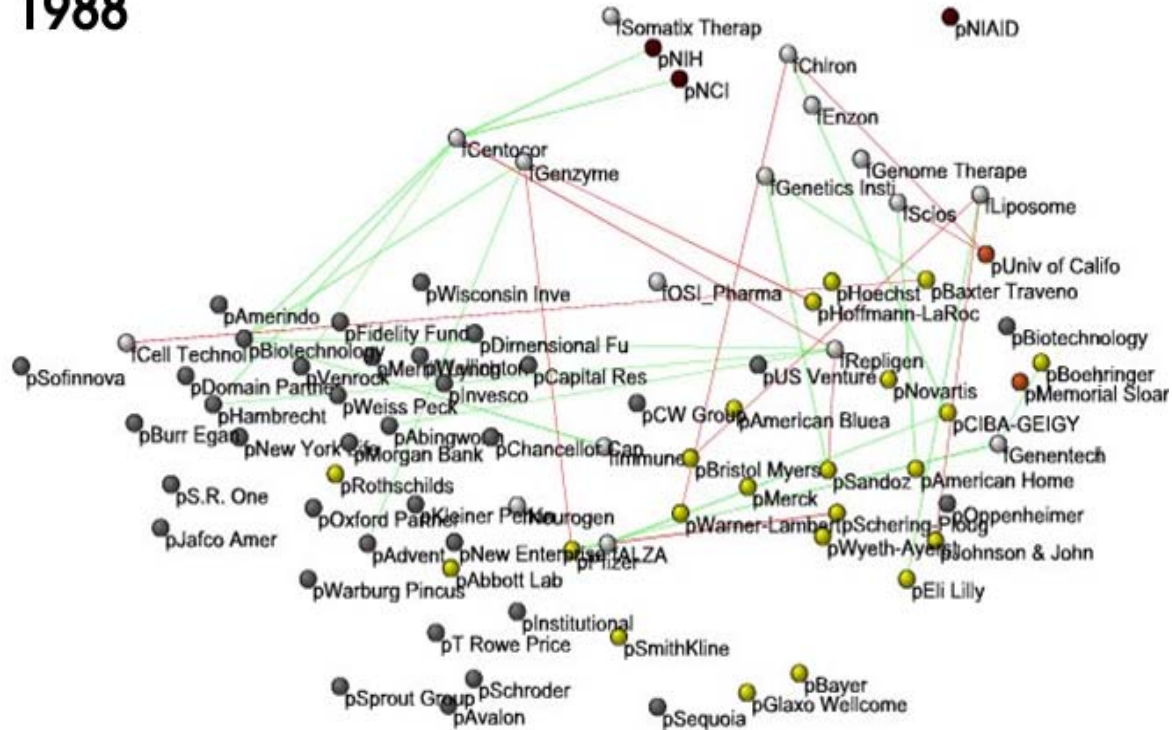
Network Connectivity \neq Complexity

Network Connectivity + Dynamics = Complexity

- They have a non-trivial topological structure dynamically evolving over time
- Buzzwords
 - Heavy tail in the degree distribution
 - High clustering coefficient
 - Preferential attachment
 - Community structure

Business ties in US biotech-industry

1988



Nodes: companies: investment

pharma

research labs

public

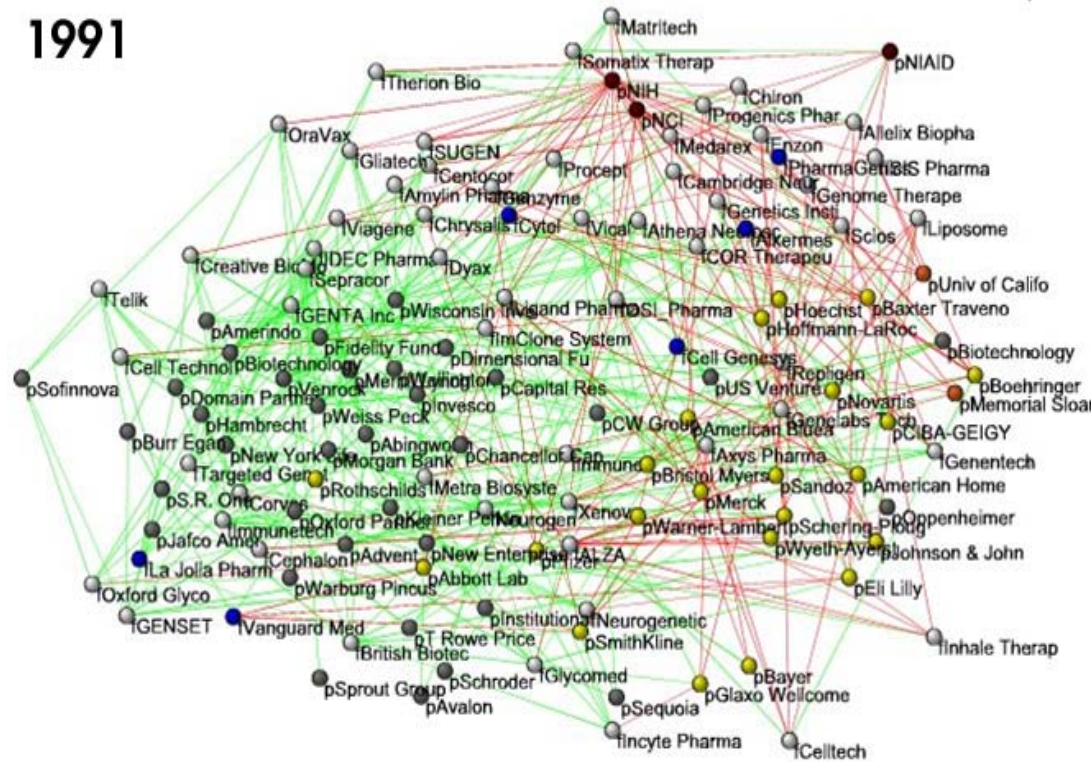
biotechnology

Links: financial

R&D collaborations

Business ties in US biotech-industry

1991



Nodes: companies: investment

pharma

research labs

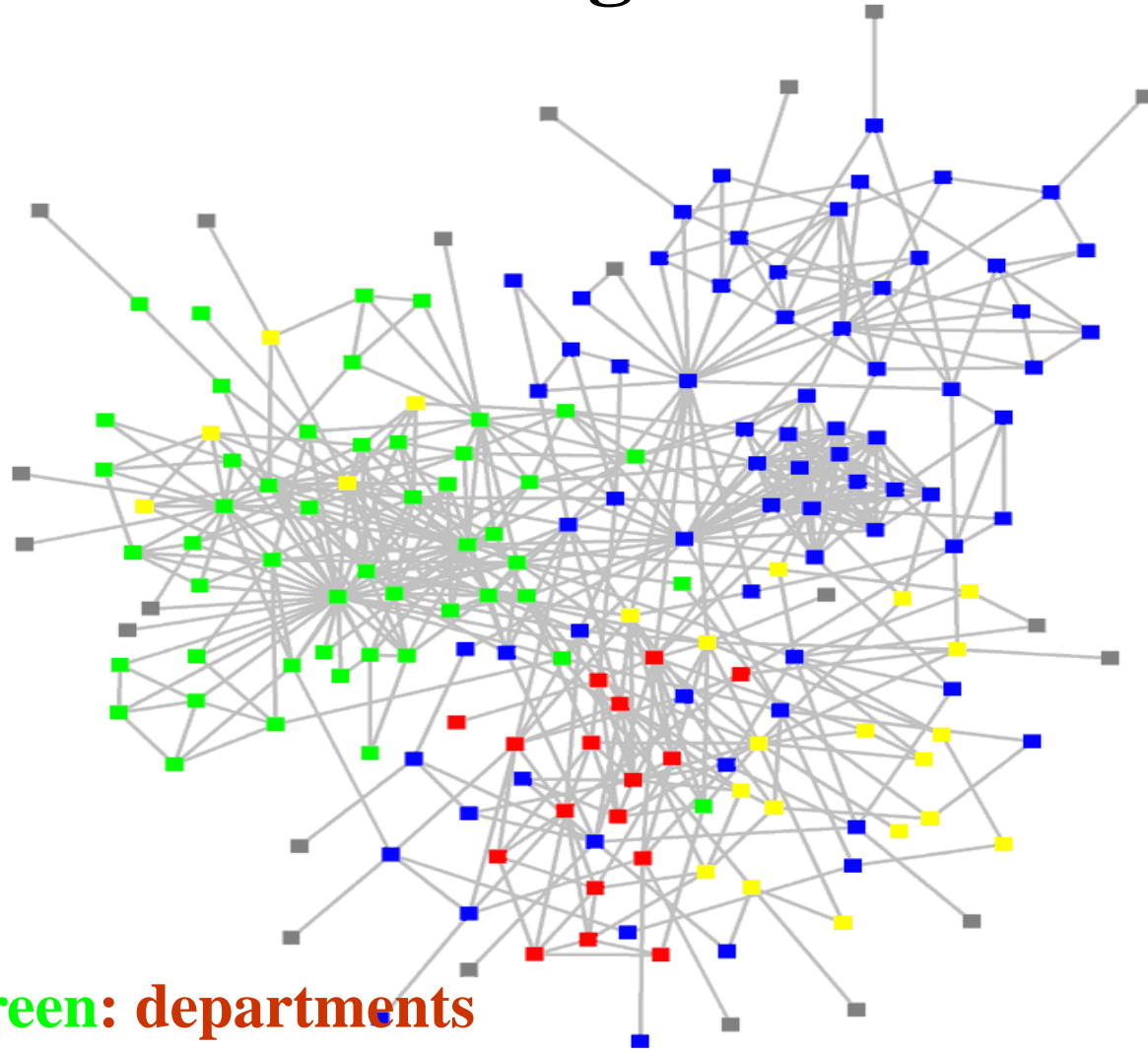
public

biotechnology

Links: financial

R&D collaborations

Structure of an organization

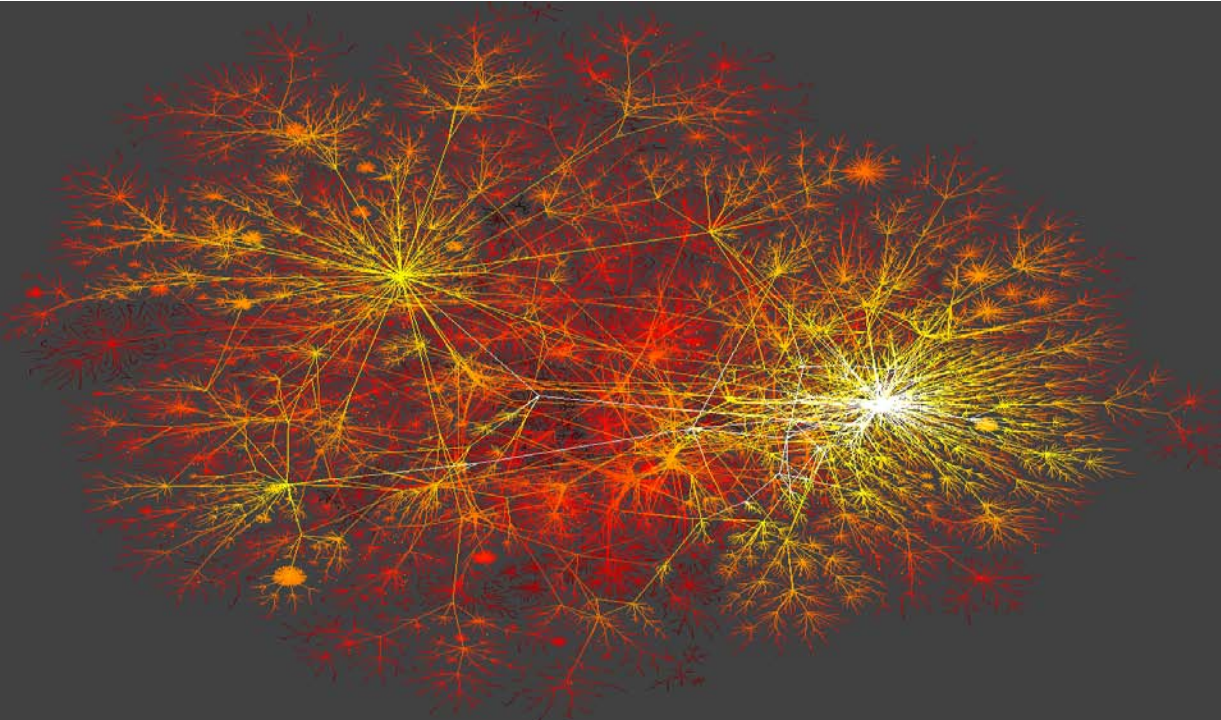
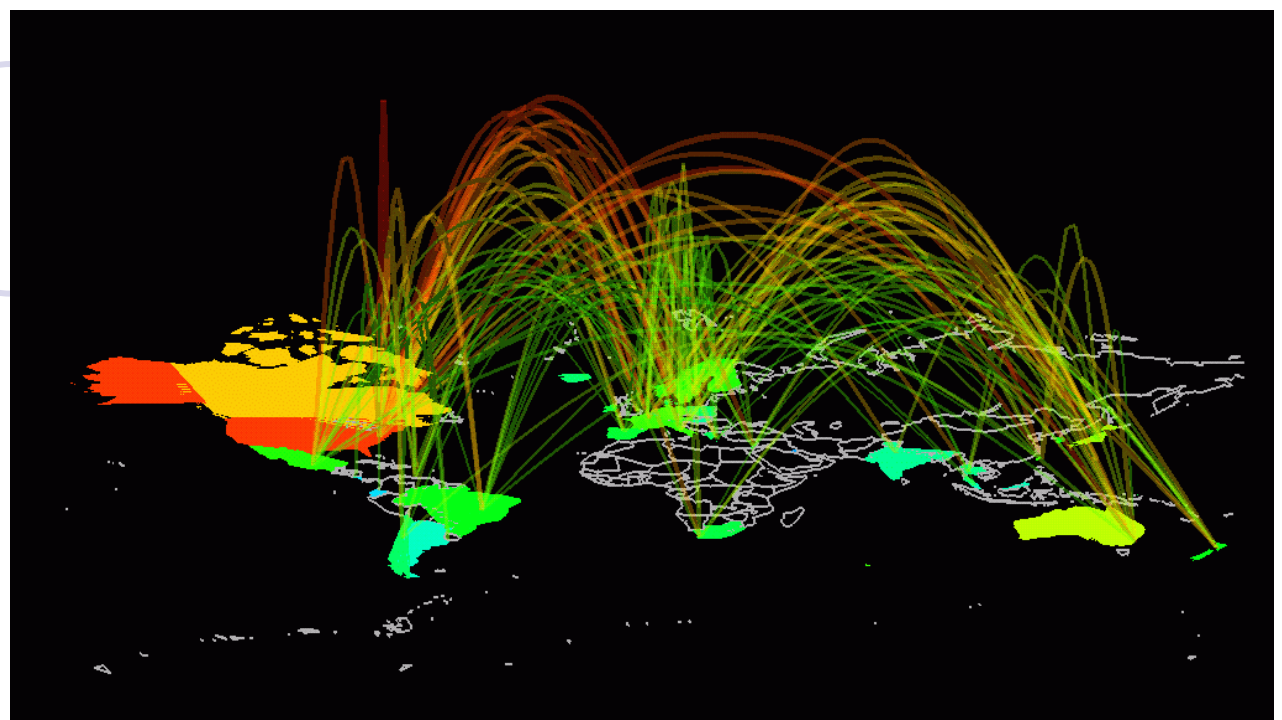


Red, blue, or green: departments

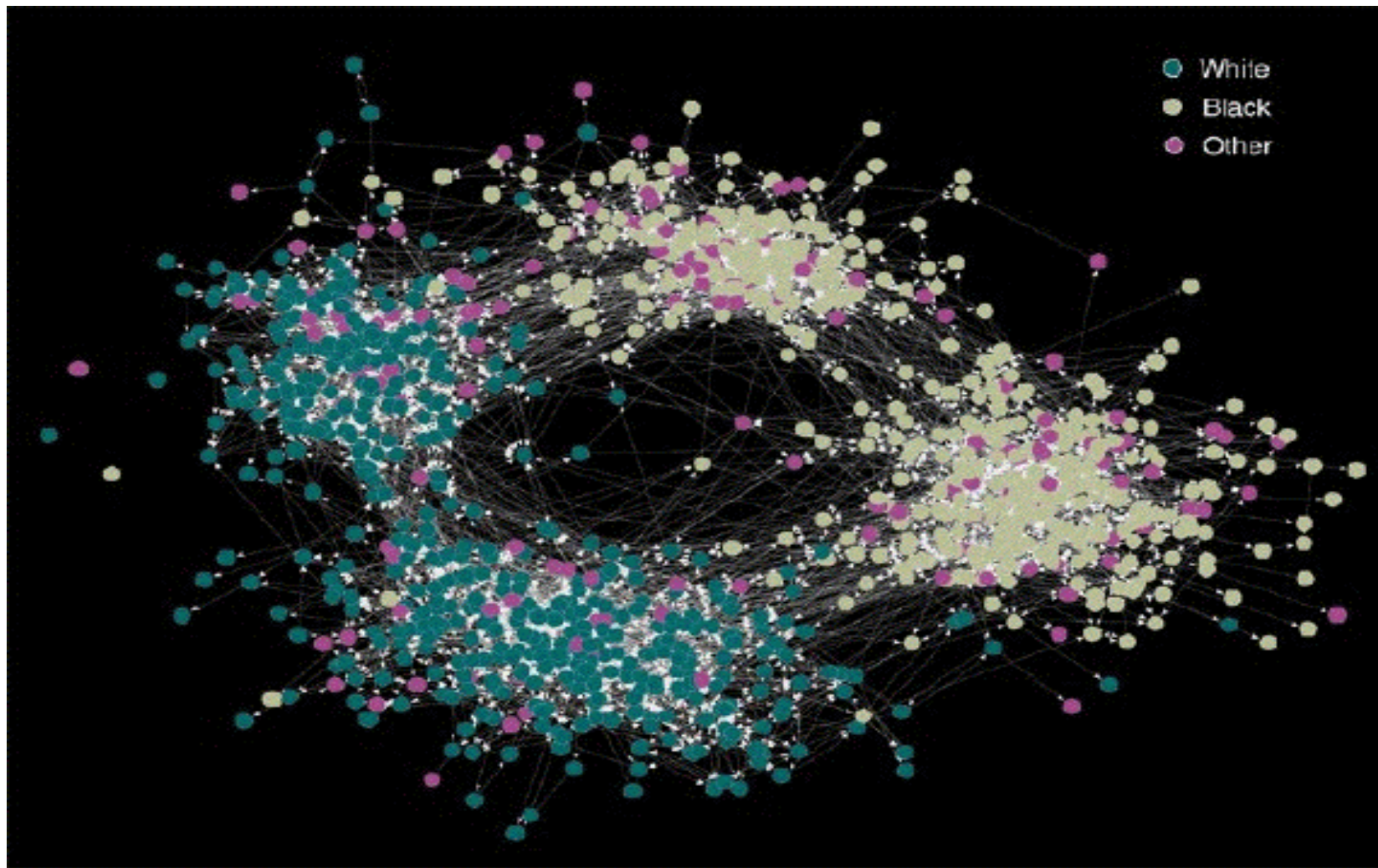
Yellow: consultants

Grey: external experts

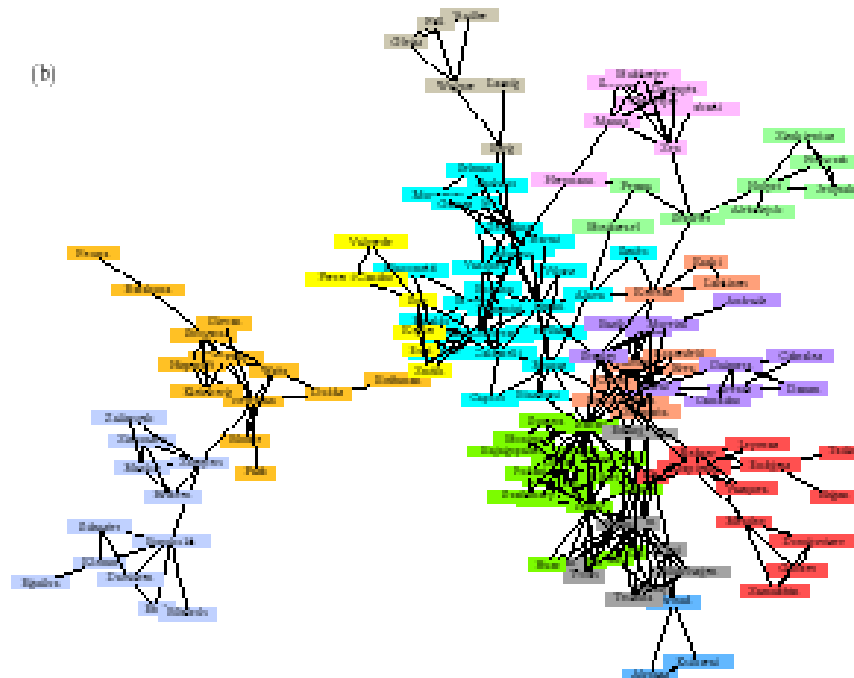
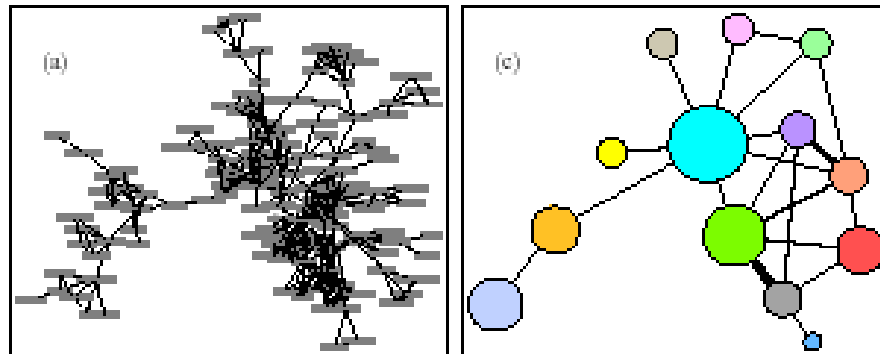
Internet

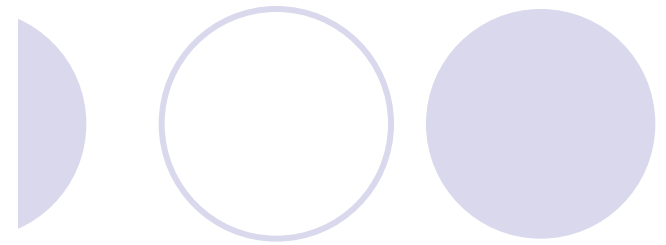


Friendship Network



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)

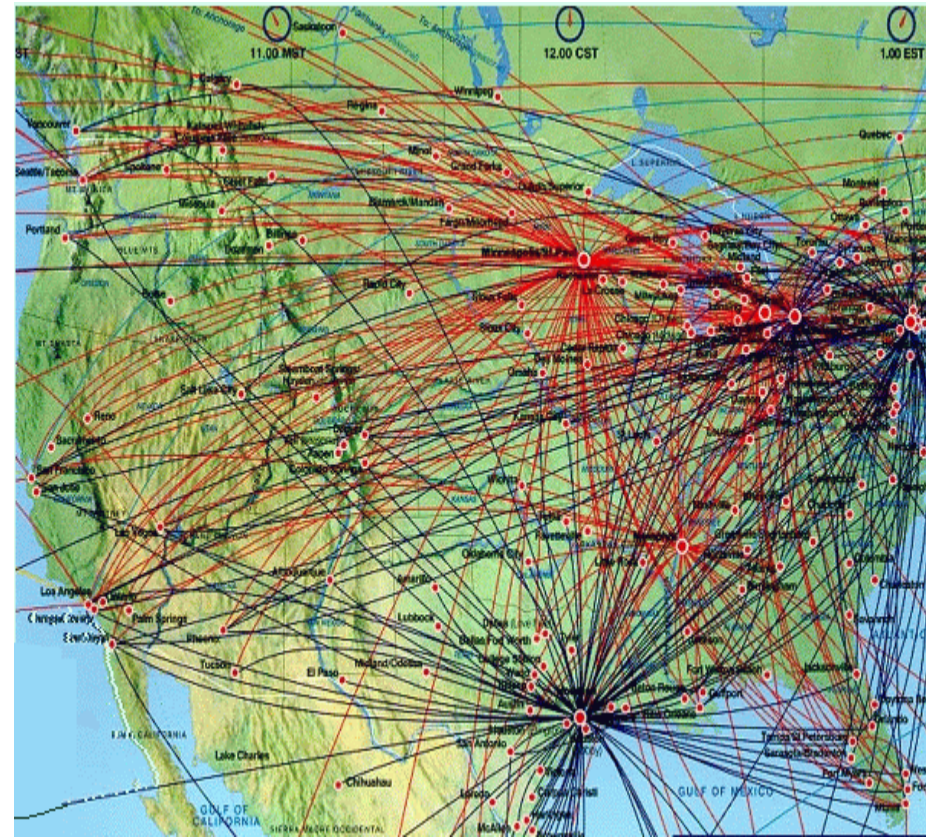
Links: sexual relationships



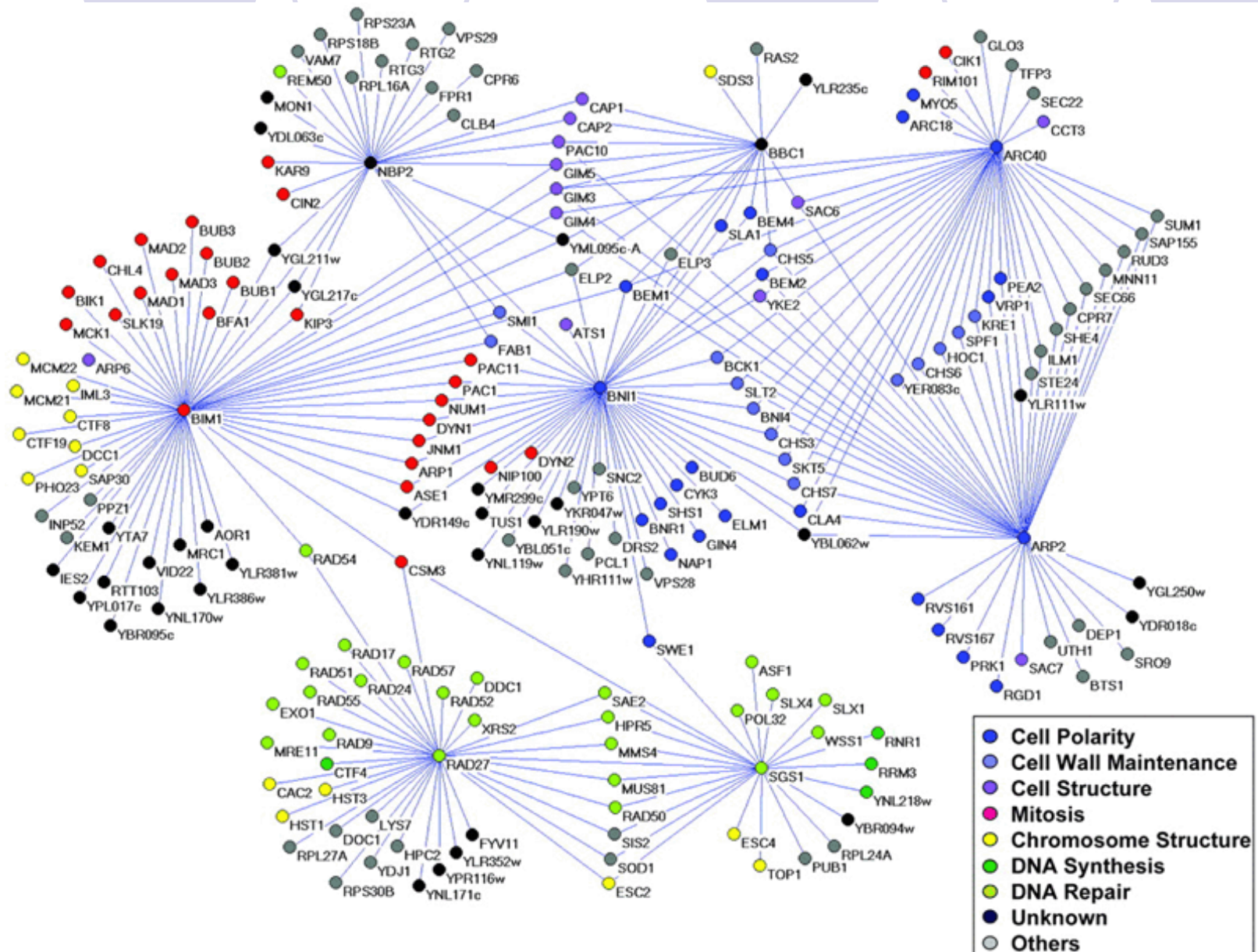
4781 Swedes; Age: 18-74;
59% response rate.

Liljeros et al. *Nature* 2001

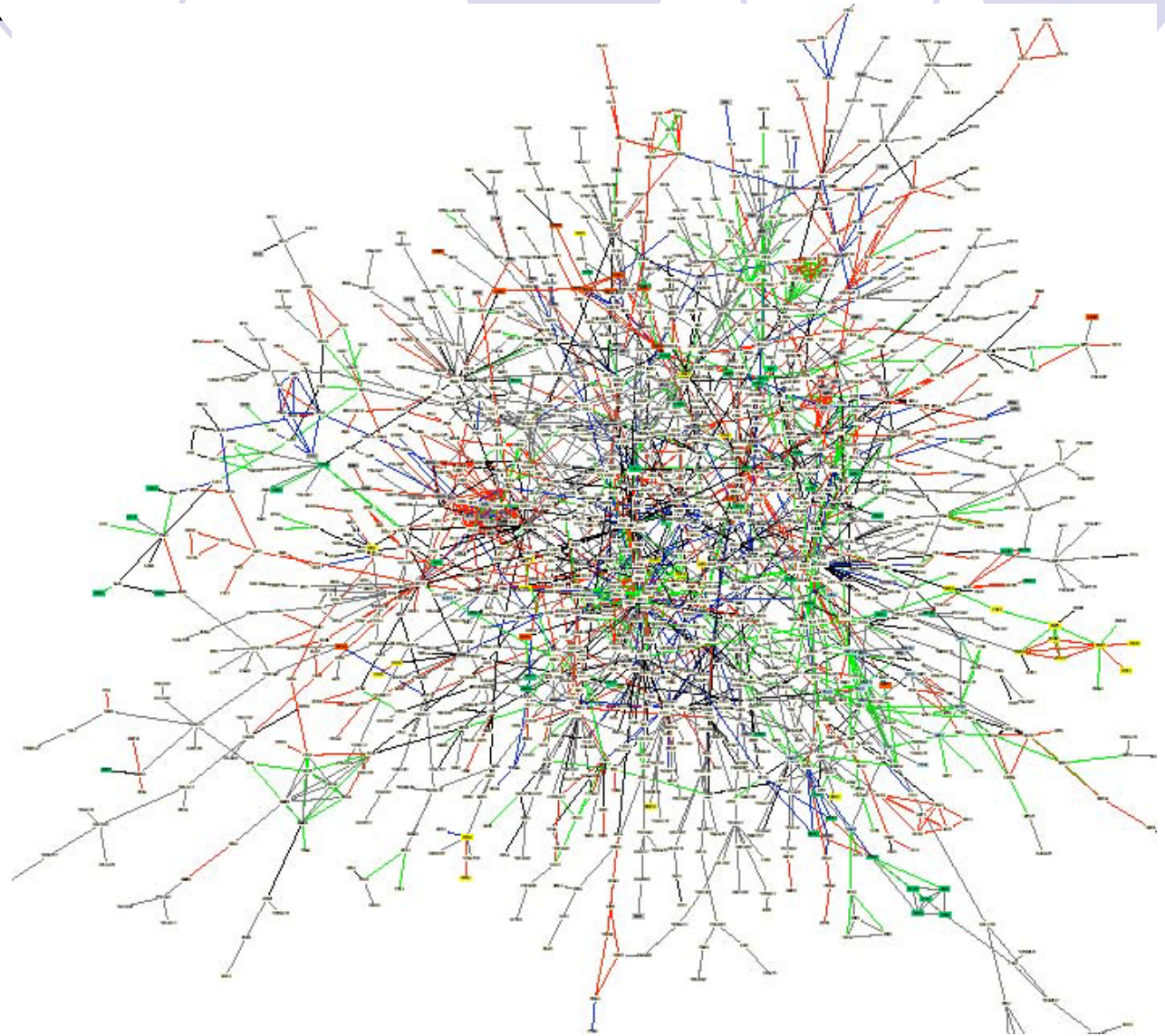
Road and Airlines Network



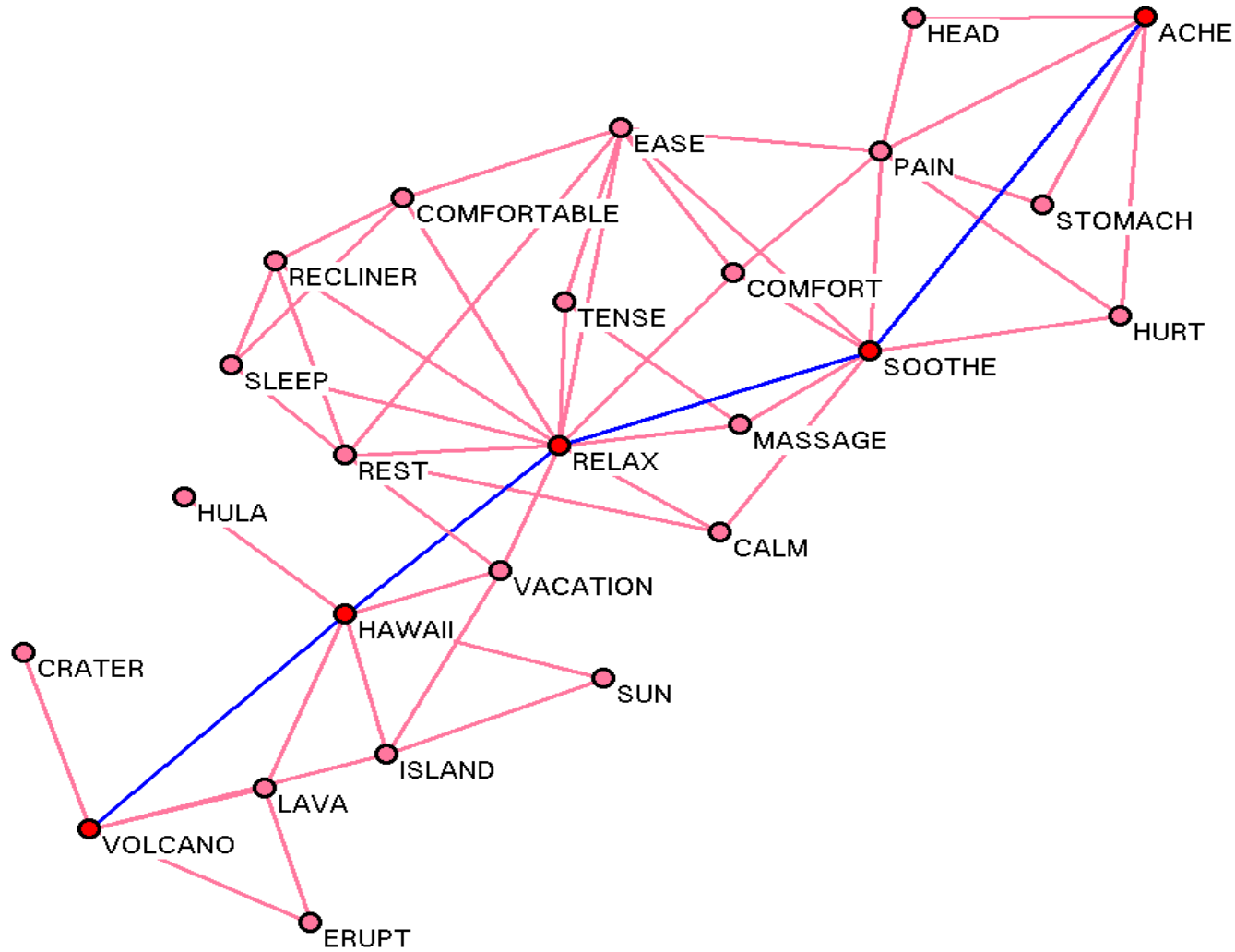
Genetic interaction network



Yeast protein-protein interaction network



Word associations

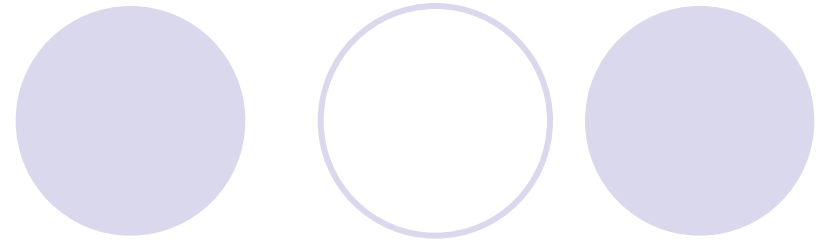


The title is centered at the top of the slide. Above the text, there are five circles arranged horizontally. The first, third, and fifth circles are solid light purple. The second and fourth circles are hollow with a light purple outline. The title text is in a large, bold, black sans-serif font.

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

2 Way Approach



- Analysis of the real-world networks
 - Degree Distribution
 - Clustering Coefficient
 - Centrality
 - Small-world effect
- Synthesis of the network by means of some simple rules
 - Preferential attachment models
 - Small-world models

Special Topic: Applications in IR/NLP

IR (ranking)

PageRank

HITS

NLP

Graph based on distributional hypothesis

Cluster for word sense disambiguation

Clustering for POS induction